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RETIREMENT OF ALAN C. TAFT

The retirement of Alan C. Taft as Chief of the Bureau of Fish Conservation of the California Department of Fish and Game, effective April 30, 1952, marks the end of an outstanding, even though often turbulent, chapter in the development of California's inland fisheries program.

This period began on November 1, 1931, when Dr. John Otterbein Snyder, recently retired as head of the Zoology Department at Stanford University, was appointed chief of the bureau. Professor Snyder immediately undertook the reorganization of the unit to meet the challenges created by the rapidly increasing numbers of anglers in California and the withdrawal of fishing waters for power development and other uses. After completing the reorganization work and initiating essential long-term investigative programs, Doctor Snyder retired in 1937, and Alan Taft succeeded him. During the previous nine years he had accumulated invaluable information and experience concerning California's fisheries problems as a salmon and trout investigator for the U. S. Bureau of Fisheries.

With the perseverance and determination for which he has been noted, Alan Taft ably assumed his new responsibilities. He enlarged and developed the plans initiated by his predecessor, and under his guidance both the investigative and fish cultural programs of California won the respect and acclaim of fisheries workers throughout North America. Fish planting procedures and equipment developed under his guidance were extensively copied by other agencies. The system of stream and lake surveys was vastly expanded. New types of fish screens, the most efficient and economical yet devised, were developed. The general investigative program he promoted has supplied answers to many of the vexing problems created by an unparalleled population increase.

Long recognized as one of the ablest, best informed, and always forthright, fisheries administrators in the United States, Alan Taft had an uncanny ability to spot weak points in any plan or proposal, and to explain his viewpoint clearly and convincingly. Like all of us, he sometimes erred in his judgment, but he was never overawed by superior authority. When he thought he was right he courageously stuck to his guns, often to his own discomfiture.

While this fine public servant relinquished his administrative post much too early in life, we congratulate the Food and Agricultural Organization of the United Nations upon the promptness with which they secured his services to conduct a review of Finland's fisheries administration and legislation during the present summer.

As a parting gesture of good will and affection, his co-workers presented Alan a life membership in the American Fisheries Society. This professional organization was founded in 1870, the same year California's Department of Fish and Game was launched.

We shall miss Alan Taft's dynamic personality in our ranks. His host of friends join in wishing him many happy and productive years.—*Seth Gordon, Director, California Department of Fish and Game, May, 1952.*

THE PRONG-HORN ANTELOPE OF CALIFORNIA WITH SPECIAL REFERENCE TO FOOD HABITS¹

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INTRODUCTION

The history of the prong-horn antelope, *Antilocapra americana* (Ord), in California has followed the same general pattern that has been noted wherever antelope existed in the West. Originally, antelope were abundant in the Sacramento-San Joaquin Valleys south through the Mojave Desert region to the Mexican border and on the arid plains in the northeastern part of the State. In spite of the closed season enacted by the Board of Fish and Game Commissioners in 1854, early market hunters and the encroachment of settlement, with the accompanying agricultural development, progressively extirpated the antelope from its original range with the exception of the northeastern part of the State. In early literature, mention is made of sheep men killing antelope in large numbers, presumably to save the feed on the range for their sheep. With the advent of irrigation in the great valleys, the early farmers were confronted with depredations by antelope on their alfalfa fields and other crops. In those days the problem was solved simply by slaughtering the prong-horn. The results were drastic. A census made by the California Academy of Sciences in 1922 gave a total of 434 head of antelope in the entire State (McAllister, 1923). A more comprehensive census made by the Academy in 1924 revealed a total of 1,007 antelope. The distribution of those animals was as follows: Siskiyou and Lassen Counties had a population of 982 antelope, Fresno County 14, and Kern County 11 (McAllister, 1924). It was at this time that a number of leading conservation organizations throughout the Country took cognizance of the danger that the antelope would become extinct, and an active conservation program was put into effect. A number of California conservation organizations known as the "California Associated Societies for the Conservation of Wildlife" undertook the perpetuation of the Mount Dome antelope herd in Siskiyou County, which at one time numbered 11 antelope. The State Fish and Game Commission appointed special wardens to safeguard the remaining herds, and a predator control program was enacted (Nelson, 1925). All these measures were undoubtedly responsible for the recovery of the prong-horn antelope to their present status.

The range of the antelope in California is now restricted to the Counties of Modoc and Lassen, with small numbers being found in Siskiyou, Plumas, Shasta, and Sierra Counties (McLean, 1944). Each year the

¹ Submitted for publication March, 1952. Federal Aid in Wildlife Restoration Act, California Project 25R.



FIGURE 1. A herd of antelope as seen from a Department of Fish and Game airplane during the annual census

Department of Fish and Game conducts an aerial survey to census the antelope on their present range. The 1951 population is estimated to number 4,536 animals. In December of 1949, 143 antelope were trapped and transplanted to Mono County in an effort to extend the present range. In 1942 the first limited open season was authorized by the Legislature for the taking of 500 buck antelope. Since then, further limited antelope hunting seasons have been held (Table 1).

TABLE 1
Estimated Antelope Population and Results of Hunts, 1942-1951

Year	Estimated antelope population	Number of hunting permits issued	Number of antelope shot	Percentage of successful hunters
1942.....	3,752	452	405	90
1943.....	5,338	452	362	80
1944.....	6,147	500	322	64
1945.....	4,739	500	307	61
1946.....	2,798	Hunting season closed	-----	-----
1947.....	3,949	Hunting season closed	-----	-----
1948.....	3,592	Hunting season closed	-----	-----
1949.....	4,675	500	349	70
1950.....	3,852	Hunting season closed	-----	-----
1951.....	4,536	415	280	67

The available knowledge of the food habits of the prong-horn is very limited. The very nature of the animal and its affinity to open ranges make

such a study a difficult one. To determine forage preferences and seasonal food habits, an effort was made to obtain stomach samples for analyses and evaluation. The results of this study are contained in this article.

RESULTS OF STOMACH ANALYSES

A total of 83 antelope stomach samples have been collected and analyzed by the food habits laboratory of the California Department of Fish and Game. The results of the analyses of the antelope stomach samples obtained from the May-June, 1942, and August-September, 1949, hunter kill were published earlier (Ferrel and Leach, 1950). The major portion of these antelope were killed in the Madeline Plains area in Lassen County. This area constitutes an important part of the summer range. An additional 27 stomach samples were obtained from trap casualties from the Mud Flat area near Shaffer Mountain in southeastern Lassen County between December 12th and 19th. The collection of this

TABLE 2
Seasonal Food Habits of 83 California Antelope Expressed in Volume
Percent and Frequency of Occurrence in Percent*

	Volume percent			Frequency of occurrence in percent		
	Spring	Fall	Winter	Spring	Fall	Winter
Browse:						
Purshia tridentata	13.7	10.4	0.1	60	39	7
Artemisia tridentata	40.8	35.2	95.2	90	89	100
Chrysothamnus nauseosus	3.8	1.2		35	19	
Chrysothamnus viscidiflorus	4.1	trace		30	6	
Other browse	1.2	0.1	0.5			
Total browse	63.6	46.9	95.8			
Forbs:						
Polygonum aviculare		4.9			19	
Chenopodium murale		2.1			6	
Sisymbrium altissimum		5.1			8	
Medicago sativa		1.5			3	
Carum sp.	4.2			5		
Lomatium sp.	6.2			25		
Phlox sp.	5.1	0.6		50	17	
Balsamorhiza sp.	4.5			10		45
Eriophyllum lanatum	trace	2.2		15	17	
Haplopappus racemosus		1.7			3	
Helianthus sp.		2.8			6	26
Iva axillaris	trace	17.0		5	56	4
Lagophylla ramosissima		1.9			14	
Heliantheae	1.1			5		
Compositae	trace	2.5		40	31	11
Forb spp.	13.7	9.8	2.3			
Total forbs	34.8	52.1	2.3			
Gramineae:						
Gramineae (green)	1.1	1.0		60	40	52
Gramineae (dry)	0.5		1.9	15	28	93
Total gramineae	1.6	1.0	1.9			

* NOTE: Items listed are 1 percent or more of the diet.

Spring collection consists of 20 stomachs from May-June, 1942.

Fall collection consists of 36 stomachs from August-September, 1949.

Winter collection consists of 27 stomachs from December, 1949.

material from antelope on their winter range afforded an opportunity to compare the feeding habits of antelope over a period of three seasons.

Table 2 shows the volume percent and frequency of occurrence, in percent, of the principal plants consumed by the 83 antelope during the three periods of spring, fall, and winter. Those items in the diet bulking less than 1 percent by volume are included in Table 3, which is a supplementary list of the food items eaten.

TABLE 3
Supplementary List of Food Items Eaten by 83 California Antelope *

Scientific name	Common name	Frequency of occurrence in percent		
		Spring	Fall	Winter
Lichen	-----	5		
Bryophyta	Moss		3	
Pinus ponderosa	Western yellow pine	5		
Juniperus occidentalis	Sierra juniper	20	22	
Bromus brizaeformis	Rattlesnake chess (florets)	5		
Bromus tectorum	Downy chess (dry florets)		14	74
Bromus tectorum	Downy chess (green florets)	60	8	
Bromus sp.	Brome grass (florets)	20	11	
Hordeum sp.	Wild barley (dry florets)			15
Hordeum vulgare	Cult. barley (florets)			7
Poa sp.	Blue grass (florets)			4
Eleocharis sp.	Spike-rush		3	
Carex sp.	Sedge		6	7
Cyperaceae	Sedge family	10	3	
Liliaceae	Lily family (corms, leaf)	5		
Salix sp.	Willow	5		
Polygonum sp.	Knotweed	5	3	
Rumex salicifolius	Willow dock		28	
Rumex sp.	Dock		3	
Eriogonum sp.	Wild buckwheat	50	22	33
Chenopodium sp.	Goosefoot		14	
Grayia spinosa	Hop sage	10		
Atriplex confertifolia	Sheep fat			82
Salsola kali	Russian thistle			45
Chenopodiaceae	Saltbush family		6	4
Amaranthus blitoides	Prostrate pigweed		11	
Ranunculus sp.	Buttercup	15		
Arabis sp.	Rock cress		6	11
Lepidium montanum	Pepper-grass		8	
Lepidium sp.	Pepper-grass	15	14	
Thlaspi arvense	Penny cress		6	
Cruciferae	Mustard family	15	6	
Rosa sp.	Wild rose	5		
Sanguisorba annua	Burnet	5		
Amelanchier alnifolia	Western service berry	10		
Lupinus sp.	Lupine		6	
Medicago sp.	Medick	15		
Astragalus sp.	Rattle-weed	20		
Vicia sp.	Vetch		6	
Erodium cicutarium	Red-stem filaree	25	6	
Erodium sp.	Filaree	10	11	
Viola sp.	Violet		3	
Epilobium sp.	Willow herb		14	
Boisduvalia glabella	-----		6	
Oenothera tanacetifolia	Primrose	5		
Oenothera sp.	Primrose	5		
Eryngium sp.	Button snakeroot	10	3	
Umbelliferae	Parsley family	10		
Arctostaphylos sp.	Manzanita	10		

TABLE 3—Continued
Supplementary List of Food Items Eaten by 83 California Antelope *

Scientific name	Common name	Frequency of occurrence in percent		
		Spring	Fall	Winter
Gilia sp.	Gilia	-----	-----	11
Convolvulus arvensis	Bindweed	-----	3	-----
Polemoniaceae	Gilia family	-----	3	-----
Phacelia sp.	-----	5	8	-----
Amsinckia sp.	-----	5	3	-----
Cryptantha sp.	Nievitia	-----	6	-----
Boraginaceae	Borage family	-----	3	-----
Collinsia sp.	-----	40	-----	-----
Pentstemon deustus	Pentstemon	20	8	-----
Pentstemon sp.	Pentstemon	-----	3	-----
Valerianaceae	Valerian family	10	-----	-----
Lactuca sp.	Wild lettuce	-----	14	-----
Taraxacum vulgare	Dandelion	5	-----	-----
Crepis sp.	-----	-----	3	-----
Wyethia sp.	-----	-----	3	-----
Blepharipappus scaber	-----	-----	14	-----
Madia sp.	Tarweed	-----	6	-----
Eriophyllum sp.	-----	-----	3	19
Rigipappus leptocladius	-----	5	-----	-----
Arnica sp.	-----	5	-----	-----

* NOTE: Items listed are less than 1 percent of the total diet.

The spring diet of the prong-horn consisted of 63.6 percent browse, 34.8 percent forbs, and 1.6 percent grass. The principal browses were common sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), and two species of rabbitbrush (*Chrysothamnus nauseosus* and *C. viscidiflorus*). Important spring forbs were hog-fennel (*Lomatium* sp.), false caraway (*Carum* sp.), balsam root (*Balsamorhiza* sp.), phlox (*Phlox* sp.), and species of the sunflower tribe of Heliantheae. Forbs of lesser importance but bulking a percentage by volume were knotweed (*Polygonum* sp.), wild buckwheat (*Eriogonum* sp.), buttercup (*Ranunculus* sp.), burnet (*Sanguisorba annua*), rattlesnake weed (*Astragalus* sp.), button snakeroot (*Eryngium* sp.), and pentstemon (*Pentstemon deustus*). Grass amounted to 1.6 percent of the diet in the spring.

The fall diet of the antelope consisted of 46.9 percent browse, 52.1 percent forbs, and 1.0 percent grass. There was little change in the utilization of browse in the fall from that in the spring. Sagebrush, bitterbrush, and rabbitbrush were eaten. The principal fall forbs eaten were various species of the compositae family including poverty weed (*Iva axillaris*), *Haplopappus racemosus*, *Lagophylla ramosissima*, *Helianthus* sp., and *Eriophyllum lanatum*. Also eaten were wire grass (*Polygonum aviculare*), sowbane (*Chenopodium murale*), and tumbling mustard (*Sisymbrium altissimum*). Forbs of lesser importance were willow dock (*Rumex salicifolius*), wild buckwheat (*Eriogonum* sp.), goosefoot (*Chenopodium* sp.),

prostrate pigweed (*Amaranthus blitoides*), pepper grass (*Lepidium montanum*), lupine (*Lupinus* sp.), vetch (*Vicia* sp.), filaree (*Erodium* spp.), willow herb (*Epilobium* sp.), primrose (*Oenothera tanacetifolia*), phlox (*Phlox* sp.), pentstemon (*Pentstemon decustus*), wild lettuce (*Lactuca* sp.), wyethia (*Wyethia* sp.), *Blepharipappus scaber*, and *Boissduvalia glabella*. Alfalfa (*Medicago sativa*) amounted to 1.5 percent of the fall diet. The consumption of grass was 1.0 percent of the diet.

The winter diet consisted of 95.8 percent browse, 2.3 percent forbs, and 1.9 percent grass. Of the winter browse consumed, 95.2 percent of it was sagebrush. Bitterbrush and sheep fat (*Atriplex confertifolia*) made up the remaining 0.6 percent of the browse eaten. Forbs consumed consisted mainly of unidentified dry stems, dry leafage, and compositae involucre. These forbs which were noted in the tables were identified by the finding of seeds. A noticeable exception was the stems of Russian thistle (*Salsola kali*), which amounted to 0.7 percent by volume of the winter diet and occurred in 45 percent of the stomachs. Although there are many forbs growing on the winter range, the first days of early frost kill out such plants. The grass eaten was mainly dry grass amounting to 1.9 percent of the diet at that time.

DISCUSSION

The largest numbers of antelope in California are concentrated in southeastern Lassen County during the winter. The location of this winter range is north and east of Honey Lake Valley and extends eastward into Nevada. The antelope occupy this winter range from November to early or middle April whence they move up into the higher elevated summer range to the northwest. Weather is the factor which apparently determines the extent of the winter range and the time of migration to and from such winter ranges (McLean, 1944). It is from this herd that the stomach samples were obtained.

The significant difference between the winter and summer ranges is the presence of the herbaceous component of the range, which is lacking on the winter range following the first weeks of frosting. Forbs are high on the list of preferred foods of antelope on the summer range. Over 60 species of forbs were identified in the 56 stomachs collected in the spring and fall. The antelope's fondness for forbs has been noted by workers from other states. Buechner (1950) observed antelope to be heavy utilizors of forbs on the Trans-Pecos ranges of Texas.

It is apparent from the stomach analyses that sagebrush is the staple food of the California antelope throughout the year. The degree of utilization of sagebrush is as follows: 95.2 percent by volume for December, 40.8 percent for May-June, and 35.9 percent for August-September. Einarsen (1948), reporting on investigations made by O. J. Murie, showed that antelope were fond of forbs in the summer as well as feeding on sagebrush and that sagebrush was the important food during the winter. He went on further to say that in Oregon sagebrush was the staple food of antelope.

Chemical Analyses of Sagebrush

An index to the value of sagebrush as a sustaining food for antelope may be found in the amount of crude protein found in the stems and leafage. Einarsen (1946) has noted that black-tailed deer losses have coincided with periods when low protein levels were reached in browse plants. He cites 5 percent protein content in browse as being a critical minimum level to sustain black-tailed deer. Protein determination on sagebrush collected at Doyle, Lassen County, California, were run by Mr. Harold Bissell of the food habits laboratory, and the results are presented in Table 4.

TABLE 4
Total Protein Content of *Artemisia tridentata* *

Date collected	Sample number	Percent of total protein dry weight basis	Date collected	Sample number	Percent of total protein dry weight basis
August 30, 1950	1	9.9	December 12, 1950	167	10.5
August 30, 1950	2	10.5	January 22, 1951	118	9.7
October 3, 1950	11	9.9	January 22, 1951	124	14.5
October 3, 1950	14	12.7	February 28, 1951	248	8.9
November 9, 1950	77	11.9	February 28, 1951	249	11.6
November 9, 1950	80	10.9	April 22, 1951	317	13.7
December 12, 1950	162	10.9	April 22, 1951	318	10.2

* NOTE: Analytical procedure taken from the "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists."

Antelope are evidently able to sustain themselves on a diet largely of sagebrush and suffer no evidence of malnutrition under conditions of present antelope numbers. Limited die-off of antelope has been observed but has been attributed to unusual severity of winter weather at the time rather than nutritional deficiencies. Heavy snows and extreme freezing weather have been known to take heavy toll of antelope in other western states. Whether the digestive capabilities of antelope differ from those of deer is not known but is suggestive. There is evidence that deer die-off does occur on California sagebrush ranges when deer are forced to rely heavily on sagebrush as a winter food. This has been observed on the Doyle winter deer range during the winters of 1949 and 1950 (Lassen et al., 1952).

Antelope Limitations

Available forage on the winter range apparently is not the principal limiting factor in the production of antelope in California, as is the case with the migratory deer herds. Evidence cited by Chattin and Lassen (1950) points to a high reproductive potential as revealed by embryo counts. The existence of a static population or of one which shows a decrease in numbers must be attributed to factors other than the over-utilization of the winter range.

Most notable of the limitations on antelope numbers is the scarcity of open range. Antelope can never be re-established throughout their traditional range. The available open range is limited, and they cannot com-

patibly occupy ranges that overlap extensive areas of agricultural development.

The possibility that predator relationship may be one of the factors, if not the major one, in limiting antelope abundance has been expounded by several workers. Jones (1949) was of the opinion that predation by coyotes on antelope fawn is the chief limiting factor operating to prevent the increase of antelope in the Upper and Lower Plains regions of northwestern Texas. Einarson (1948) states "If observations of the Research Unit of Oregon are indicative, the coyote is a formidable foe of all age classes of the pronghorn." Gabrielson (1941) cites the effect of predator control by the Biological Survey in the territory adjoining the common boundary of California, Nevada, and Oregon as responsible for the increase in population from 500 in 1921 to the present population of 7,000 to 8,000 animals. Nelson (1925) recommends the trapping of predatory animals before antelope can be perpetuated on fenced ranges and in game refuges covering large areas. Recently Jones (1949) recommended that in restocking antelope to other ranges an extensive predator control program must be initiated to insure success of the transplant.

The competition for food between antelope and livestock has been mentioned as a limiting factor. According to Buechner (1947) the most important limiting factor to antelope increase in the Trans-Pecos region of Texas has been the intense food competition between antelope and sheep. He goes on to say that the competition between antelope and cattle and horses is practically nonexistent. However, it must be noted that the range occupied by antelope in Texas is of a plant association differing from that found on the antelope range in California. It is the opinion of the authors that perhaps with local exceptions there is probably no severe competition between livestock and antelope on California ranges under present conditions of antelope populations. The antelope, being a highly mobile animal, moves about over a larger area than sheep in the search for food, and as a result distributes the grazing pressure widely over the range. The amount of grass eaten by antelope is negligible. Many of the important forbs utilized by antelope are not palatable to sheep or cattle, and many such forbs are indicators of overgrazing by livestock.

At the present antelope numbers, there is little conflict between agriculture and the antelope. The most common depredation caused by antelope is the invasion of alfalfa fields and pastures, with some consequent breaking down of fences. Damage is also done to grain fields, not by the grain consumption of the antelope but by their trampling and bedding-down activities. The source of many complaints, undoubtedly, is the rancher who observes these large animals on his range and assumes that the antelope are consuming food needed by his livestock.

SUMMARY

A total of 83 antelope stomach samples was analyzed. Common sagebrush was revealed to be the staple food for antelope over the spring, fall, and winter periods. Forbs are eaten in considerable variety and bulk in the spring and fall. The consumption of grass is negligible.

Limited open range land, predator relationship, and livestock competition for food are mentioned as possible limiting factors on antelope numbers.

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THE EFFECTS OF SODIUM FLUOROACETATE (1080) ON CALIFORNIA QUAIL¹

By KENJI SAYAMA and OSCAR BRUNETTI
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INTRODUCTION

The discovery of sodium fluoroacetate as an effective and powerful rodenticide (Kalmbach, 1945) was hastened by World War II, for critical shortages existed in certain of the materials formerly used for rodent control and an effective substitute was needed. The value of this compound was discovered by the Wildlife Research Laboratory of the U. S. Fish and Wildlife Service in Denver, which had the search for new rodenticides as one of its long established programs. They were assisted by chemists of the Economic Investigation Laboratory at the Patuxent Research Refuge in Maryland. During the period between July, 1944, and August, 1945, more than a thousand substances, largely synthetic in origin, were prepared or obtained from different cooperators and bio-assayed at the Patuxent Laboratory and the more toxic ones subjected to confirmatory tests at the Denver Laboratory. Several potentially effective rodenticides were disclosed in the course of this work, but the one commonly referred to under its laboratory number, 1080, and chemically known as sodium fluoroacetate was found particularly promising.

Sodium fluoroacetate had been known for a long time to be toxic to invertebrates and was patented in 1927 as a preservative against moths. Its destructive effect, while appreciated at the time of its initial use as a rodenticide, has become more and more apparent with its increased use. It is a water-soluble poison which is deadly in extremely minute amounts, not only to rodents but also to livestock, wildlife, pets, and even to human beings. This extreme toxicity, together with the added fact that there is no chemical test or effective antidote for the poison, makes it apparent that this chemical should be treated with great respect. Recently, sodium acetate and ethanol have been demonstrated to act synergistically to antagonize 1080 poisoning in mice if administered immediately (Tourtelotte and Coon, 1951).

In the State of California, its possession and use are strictly defined under the provisions of Section 1066.6 of the Agricultural Code in order to insure maximum protection against indiscriminate use of this poison. It is the policy of state and county agricultural officials engaged in field rodent control to exercise every precaution to protect quail and other wild birds. Therefore, it is standard practice first to expose unpoisoned baits to determine acceptance by the rodents before poisoned baits are used. Furthermore, baits are dyed a distinctive color so as to make them unattractive to birds. While this does not reduce their effectiveness as

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rodenticides, the work of Kalmbach (1943) and others has demonstrated that such coloring is effective as a bird repellent.

Research conducted on this poison since the termination of World War II has been on the pharmacological, biochemical, and physiological aspects of 1080 poisoning in birds and mammals (Chenoweth and Gilman, 1946; Foss, 1948; Ward and Spencer, 1947), along with work conducted by investigators interested in its possible effect on livestock due to secondary or accidental poisoning (Frick and Boebel, 1946; Jensen, et al., 1948). This study was conducted in order to learn more about its effect on wildlife, and also to learn whether the symptomatology or histopathology was of any diagnostic value. The California quail was selected as the experimental bird for this investigation. It must be emphasized that the symptoms and pathology described herein were obtained under laboratory conditions in which the birds were force fed aqueous solutions of 1080. Furthermore, the findings reported in this study do not mean that normal and proper use of 1080 as a rodenticide is a threat to quail populations because the State Department of Agriculture policy directs that the material be used under supervision in field rodent control.

MATERIALS AND METHODS

Several grams of sodium fluoroacetate were obtained from the Bureau of Vector Control, California Department of Public Health. The eight birds used were all adult California quail, *Lophortyx californica*.

On the basis of the report of Biester and Schwarte (1948) that the minimal lethal dose for chickens is about 14 mg./kg. of body weight, six quail were given 0.5, 1.0, 5.0, 10.0, 15.0, and 20.0 mg. of sodium fluoroacetate per kg. of body weight respectively, administered orally as a 0.1 percent aqueous solution. Two birds were given 1 ml. each of untreated water for control. All birds were kept in pairs in wire cages and supplied with water and feed. In order to study the effects of chronic 1080 poisoning, the birds that survived this initial feeding were given daily doses of approximately one-half the lethal dose as determined above, until death resulted. Each time the poison was administered to the test birds, the control birds were fed 1 ml. of untreated water, and they were sacrificed at the end of the experiment.

All birds were autopsied upon death; gross pathology was noted, and organs including the brain, lung, heart, liver, spleen, and kidney were removed and fixed in 10 percent formalin. Histological sections cut 8 micra thick and stained with hematoxylin eosin were prepared from the organs of both the control and the test birds. The latter slides were examined for possible pathological changes brought about by the poison.

DISCUSSION

Six quail were used to determine the minimal lethal dose of 1080. Table 1 shows the body weight of the birds, dose given each bird, actual amount of poison administered orally calculated from the body weight, and the results.

This data shows that the minimal lethal dose of 1080 for quail is less than that for chickens, being between 1 and 5 mg./kg. of body weight. Since an insufficient number of birds was used, additional studies will

have to be conducted when more birds are available before a minimal lethal dose can be accurately established. A comparison of the approximate value for quail with the values reported for 13 other kinds of birds by Ward and Spencer (1947) places the quail at the highly susceptible end of the scale. Although the L. D. (lethal dose) 100 figures were not available, the approximate L. D. 50 varied from 2.0 mg./kg. in pigeon to above 50.0 mg./kg. in the black vulture on the "fed" basis.

Death due to a lethal dose of sodium fluoroacetate occurred in approximately three hours. The birds became very inactive within two hours of the administration of 1080. They stood almost motionless with feathers fluffed out, the only motion being the slow opening and closing of the eyelids. When the investigator's hand was placed in the cage no startled reaction, characterized by the bird flying about the cage in an attempt to avoid being caught, was elicited. With the weakening of the legs which soon followed, the bird assumed a prone position and remained in a comatose state until death occurred. This picture of general inactivity until the time of death was interrupted just prior to death by a convulsive fluttering of the tail feathers of several seconds' duration.

Upon autopsy of these birds, no gross pathological changes were noted except that the heart and liver appeared slightly hyperemic. This lack of any obvious pathology is apparently due to the fact that the birds died so quickly that gross pathological changes did not have sufficient time to develop.

In order to test the chronic effects of 1080 the two birds that survived the initial experiment were given additional poison. The daily dose administered was 0.33 ml. of a 0.1 percent solution of 1080, which is approximately one-half the lethal dose for a 150 gm. bird as determined above. Although both birds survived the first three daily feedings of the poison with only slight toxic effects, the cumulative effect was sufficiently high to cause the death of both birds following the fourth feeding the next day. The symptoms displayed by these birds were similar to that described above for birds fed an initial lethal dose. Upon autopsy, the heart and liver were more hyperemic and congested with blood than was the case in the birds which died from the administration of one lethal dose. The liver was extremely fragile and difficult to remove. No other pathology was noticed.

The two control birds were sacrificed after the death of the last two test birds. All organs from both controls appeared normal.

Histological sections prepared from the brain, lung, heart, liver, spleen, and kidney were examined microscopically. The findings are shown in tabular form in Table 2 and summarized below.

Brain—The only apparent change brought about in the brain by 1080 poisoning is hyperemia of the capillaries of the cerebral cortex and choroid plexus.

Lung—Although no clear-cut effect of 1080 poison was observed in the lungs, such changes as focal areas of lymphoid-like cell infiltration, hyperemia, venous engorgement, and fibrinous exudate on the bronchial epithelium were observed which were absent in the controls.

Heart—The effects of 1080 on the heart consist essentially of hyperemia and focal areas of fatty infiltration and interstitial hemorrhage.

Liver—The most pronounced effect of 1080 poisoning was observed in the liver and consisted of sinusoidal engorgement and severe diffuse fatty degeneration. Mild hydropic degeneration was observed in both untreated birds as well as what appeared to be changes produced by increased glycogen storage.

Spleen No change

Kidney Very few changes were observed in the kidney, with possible interstitial hemorrhage and slight hyperemia being observed in birds Nos. 1 and 2.

Although the majority of these pathological changes were brought about by sodium fluoroacetate, their lack of specificity precludes their use as positive means of diagnosing birds for 1080 poisoning.

SUMMARY

Sodium fluoroacetate is extremely toxic to California quail. Although insufficient birds were available to make an accurate determination of the minimal lethal dose, it was found to lie between 1 and 5 mg./kg. of body weight.

Death due to a minimal lethal dose of sodium fluoroacetate occurs in about three hours in California quail. The birds first become inactive, standing stationary with fluffed wings and finally assuming a prone position in a comatose state. Death is preceded by a convulsive fluttering of the tail feathers of several seconds' duration.

Upon autopsy, the only obvious gross pathological changes are hyperemia of the heart and liver, with extreme fragility of the liver.

The general histopathological picture of sodium fluoroacetate poisoning in quail is hyperemia of the brain, liver, lungs, heart, and kidney. The heart is further characterized by fatty infiltration and focal areas of interstitial hemorrhages, and the liver by sinusoidal engorgement and severe diffuse fatty degeneration.

Although pathological changes were produced in the quail by sodium fluoroacetate, the lack of specificity precludes pathology as a means of diagnosis for 1080 poisoning.

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TABLE 1
Results of Administration of Varying Amounts of 1,080 to Quail

Bird number	Body weight	Dose	Amount administered	Result
Test birds				
1	165 gm.	0.5 mg.	0.0825 mg.	Survived
2	168	1.0	0.168	Survived
3	174	5.0	0.870	Died
4	175	10.0	1.75	Died
5	155	15.0	2.325	Died
6	144	20.0	2.88	Died during administration of poison
Control birds				
7	158	1 ml. water administered		Survived
8	169	1 ml. water administered		Survived

TABLE 2
Histopathological Findings on 1,080-poisoned Quail and Controls

Brain	Lung	Heart	Liver	Spleen	Kidney
a) Administered one lethal dose (1) Slight capillary hyperemia.	Fibrinous exudate on bronchial epithelium. Occasional lymphoid-like cell infiltration around arteriole.	Negative.	Severe diffuse fatty degeneration. Sinusoidal engorgement. Hyaline thrombi in central vein.	No slide.	Hyperemia. Possible interstitial hemorrhage.
(2) Capillary hyperemia of cerebral hemisphere and choroid plexus.	Venous engorgement.	Focal areas of interstitial hemorrhage. Areas of fatty infiltration.	Same as above.	Negative.	Same as above.
(3) Same as above.	Hyperemia. Focal areas of lymphoid-like cell infiltration especially around bronchi.	Interstitial hemorrhage. Coronary vessel hyperemia.	Same as above. Sinusoidal engorgement.	Negative.	Negative.
(b) Administered four sublethal doses (4) Same as above.	Same as above.	Hyperemia.	Cloudy swelling. Focal areas of fatty degeneration. Sinusoidal congestion.	No slide.	Negative.
(5) Same as above.	Hyperemia.	Hyperemia. Fatty infiltration.	Hydropic degeneration especially around central vein.	Negative.	Negative.
c) Controls (6) Capillary hyperemia.	Negative.	Negative.	Hydropic degeneration. Increased glycogen storage.	Negative.	Negative.
(7) Capillary hyperemia.	Pigment granules diffuse throughout lungs.	Negative.	Same as above.	Negative.	Negative.

CALIFORNIA'S PART IN A THREE-STATE SALMON FINGERLING MARKING PROGRAM¹

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To Mr. John Pelnar, District Supervisor, United States Fish & Wildlife Service, we owe perhaps the most. It was largely through his efforts that nearly a quarter million fingerling salmon were made available to the State for marking. He also placed at our disposal the facilities at Coleman Hatchery for the marking of both hatchery-raised and wild fish.

Mr. Stephen C. Smedley, Foreman of Prairie Creek State Fish Hatchery, gave extensive assistance in the handling of fish, and much valuable

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information about the silver salmon spawning streams in Humboldt and Del Norte Counties.

Mr. Frederick K. Cramer, and Mr. William A. Davenport of the Fish & Wildlife Service gave detailed information about salmon in the Red Bluff area and contributed captured salmon from the Sacramento River for marking.

Captain Leslie E. Lahr and other state fish and game wardens in the north coast area volunteered much valuable information concerning silver salmon streams.

Many members of the staff of the Bureau of Marine Fisheries labored long and odd hours to construct equipment and capture fingerling salmon in the numbers required. Messrs. Don L. Stoffer, Otis F. Corley, Robert F. Elwell, and Joe F. Patterson were key men in this work. To them and to the others we extend our heartiest thanks.

INTRODUCTION

The problems of fisheries management are requiring ever increasing knowledge of the behavior of our more important fishes. Some of the fisheries are interstate or international in scope, but for many years research and management on some of the species was conducted with little coordination between states and much resulting loss of efficiency. In 1946, official representatives of California, Oregon, and Washington formed a compact creating the Pacific Marine Fisheries Commission to make such coordination possible. The Congress of the United States granted its consent and approval on July 24, 1947. Meetings conducted by the commission are rotated among the three states and are attended by representatives of the fishing industry, fishermen, and biological staffs of the three states. Representatives from Canada, Alaska, and the U. S. Fish & Wildlife Service also attend. Meetings of a small number of fisheries biologists from the three states are held annually and are attended by Canadian and Fish & Wildlife Service staff members.

One of the problems of the commission has been that of the ocean fishery for king and silver salmon (*Oncorhynchus tshawytscha* and *O. kisutch*). Of the five North American species of Pacific salmon, only these two are commonly taken as far south as California, and only these two are regularly taken by sportsmen or by commercial trollers. These species present problems that cannot be solved by one state at a time. For example, most of California's commercial silver salmon catch appears to come from Oregon streams; Sacramento River kings are taken off Oregon and Washington; and Columbia River kings move to Alaska in quantity. Obviously, the ocean fishing regulations in one state can affect the ocean and stream fisheries of its neighbors and, conversely, what happens in the streams of one state can be equally far reaching.

One of the first steps in the coordinated salmon study was a tagging (Petersen disc) program intended to give a start towards a more complete and quantitative knowledge of the movements of salmon, and to learn if there have been any important changes since earlier tagging experiments were conducted. Fisheries workers of California, Oregon, Washington, Canada and Alaska have all engaged in tagging ocean-caught salmon and in the recovery of these tags. Uneven effort at tag recovery has been one of the greatest faults of earlier experiments.

A second experiment, intended to supplement the tagging, is involving the *marking* of king and silver salmon fingerlings, and the recovery of these marked fish. To summarize the differences between the experiments: The *tagging* has involved putting numbered tags on thousands of relatively large ocean-caught salmon. The fish are recovered in the ocean and in the streams. The stream of origin of an individual fish cannot be determined with certainty if the fish is retaken in the ocean. Marking will involve the clipping of two fins from each of several million fingerlings in fresh water, using a different combination of fins for each of the groups of fish marked during any one season. Obviously, the stream of origin of an ocean-caught marked fish can be determined. Only a limited number of groups can be marked in any season because there are relatively few combinations of fins which are suitable.

Extent of the Marking Program

Representatives of the biological staffs of the three states met with biologists of Canada and the U. S. Fish & Wildlife Service on November 21-22, 1949, to discuss several fisheries problems and to organize the salmon-marking program. The Canadian and federal men did not intend to participate in this marking experiment, but previous experience in similar work enabled them to give valuable assistance in the planning.

It was decided that in order to obtain adequate numbers of recoveries, it would be desirable to mark about 100,000 silver salmon or 200,000 king salmon in each group released (one mark for each group). The numbers selected were based on the rate of return from previous marking experiments. The reason for proposing the marking of a smaller number of silver salmon is that fishes of this species could be released as yearlings and would probably have much higher survival rate than the kings, most of which would be released when only a few months old.

Eight two-fin and two three-fin marks² were selected as being suitable for an experiment of this magnitude. The purpose of the experiment was explained by letter to all other organizations which might be interested in marking king or silver salmon, and exclusive use of these marks was requested. This was granted by all organizations concerned.

As a by-product of this experiment, the research coordinator of the Pacific Marine Fisheries Commission has taken over the thankless job of acting as a clearing house for marking experiments. Any organization which wishes to mark any trout or salmon now contacts the Pacific Marine Fisheries Commission, states its needs, and asks for the use of a mark or marks. It is then assigned marks which will not interfere with other experiments. This arrangement is entirely voluntary, but it works satisfactorily.

Reasons for Use of "Wild" Fish

In carrying out this investigation, one important question involves the use of hatchery-reared fingerlings. Can salmon which spend their first few months in a hatchery be used to determine the movements of the "wild" fish which hatch in the streams of the same area? The indications from earlier marking experiments are that the hatchery fish can be so

² Adipose and left ventral, adipose and right ventral, adipose and anal, dorsal and left ventral, dorsal and right ventral, dorsal and anal, anal and left ventral, anal and right ventral, adipose and both ventrals, dorsal and both ventrals.

used, but the evidence is not sufficiently complete to remove all doubt. To check on this point, California agreed to mark a minimum of 200,000 wild king salmon and 200,000 hatchery kings in the same area.

To mark California's first year's quota of silver salmon required the use of wild fish for another reason — there were no hatchery-reared silvers available in the State.

Sources of Hatchery Salmon in California

The available sources of hatchery salmon in California are limited. At present, there are only three hatcheries in the State which regularly handle salmon. Coleman Fishery Station is a large federal king salmon hatchery. It is on Battle Creek near the Sacramento River. Mt. Shasta Hatchery is a large Department of Fish and Game trout hatchery which handles some salmon. It is near the headwaters of the Sacramento River, many miles above the farthest point which salmon can now reach. All salmon eggs must be transported to the hatchery. The Prairie Creek Hatchery in Humboldt County is another Department of Fish and Game trout hatchery which handles some salmon. It is not large but it is the only one of the three within a reasonable distance of a source of silver salmon eggs. When the marking experiment was started, all of Prairie Creek Hatchery's available space was being utilized by trout and king salmon. It is now rearing some silver salmon which will be marked and released in the spring of 1953.

Scope of This Report

This report covers the first two years of salmon marking by the California Department of Fish and Game, and is primarily concerned with the problems involved in capturing and marking "wild" or naturally spawned salmon, king and silver.

Brief Comparison of King and Silver Salmon

The common range of both king and silver salmon is from Monterey Bay north to Alaska and south on the Asiatic coast to the Amur River. Each is occasionally taken as far south as Southern California. There are no king salmon spawning runs of any consequence in streams south of the Golden Gate. King salmon do not spawn in many of California's smaller coastal streams; they do prefer the larger streams and are most abundant in the Sacramento-San Joaquin River System. Silver salmon utilize many of the small coastal streams from Monterey County northward, but only rarely is even a single stray taken in the Sacramento-San Joaquin system. Several of the State's larger coastal rivers such as the Smith, Klamath, Mad, Eel, Van Duzen, and Mattole Rivers have runs of both species. In general, the kings spawn in the gravel bars of the main stem or larger tributaries while the silvers use the smaller branches.

Wherever spawned, the silvers spend their first year in the smaller streams and migrate to sea at an age of about 15 months. At this time, most of them are about five or six inches long. The majority return to spawn at the age of three years, and they will usually weigh between 7 and 12 pounds at this time. The remainder of the spawners are two-year-old "jacks." In more northern waters (especially Canada and Alaska) there are some four-year-old silvers.

Most California king salmon migrate to sea during their first year. Many leave the streams when less than two inches long. Some kings remain in fresh water over a year, but in California the proportion is low. The greatest number return to spawn at four years; next in abundance are three-year-olds. Five- and two-year-old spawners are common; yearlings and six-year-olds relatively scarce. A four-year-old fall run Sacramento River king salmon will weigh about 20 pounds.

CAPTURING WILD KING SALMON FINGERLINGS

The salmon marking program in 1950 called for the fin clipping of 200,000 young king salmon native to the Sacramento River. No attempts had been made before in California to capture wild salmon in any such quantity. However, small numbers of young kings had been taken by various means during the course of salmon investigations on Central Valley streams, and the behavior and habits of these fish were well understood.

Most young king salmon start their migration from the spawning beds to the sea in the early spring months, shortly after emerging from the gravel. A few kings remain in fresh water during their first year of life if summer water temperatures are low enough to permit survival. Small kings migrate principally with the water currents. If the water is clear, most of the fish will move at night and spend the day hiding along brushy banks or in other protected places. If the river rises suddenly or becomes extremely muddy, the daytime movement increases and may equal the nocturnal migration. A limited number of experiments with nets set at different depths indicate that in California streams, most migrants travel close to the surface even in deep areas of the river.

Fishing Methods Previously Used

When the marking program was started, anchored fyke nets had been in use for years to sample downstream migrating salmon in the Sacramento-San Joaquin and other river systems. A fyke net is essentially a tube or cone of netting, open at one end, and closed at the other. (Figure 2.) One or more funnel-shaped "fykes" in this tube make it easy for the fish to get in and hard for them to get out. When used to catch downstream migrating salmon, such nets are fished with the open end upstream and simply strain the fish out of the water as they drift with the current. If it is to be used in deep water, the webbing is hung on circular hoops. If it is to be used on the bottom in shallow riffle areas, the frames are rectangular. Both types of net are highly size selective as most salmon over 45 mm. in length will avoid being trapped unless the net is fished in very swift water. Water velocities high enough to capture larger fish will cause a high mortality in the catch.

Two-man seines of one-half inch stretched mesh (one-fourth inch bar mesh), 15 feet long by 3 feet deep, were used successfully on several occasions in netting small salmon in the Tuolumne and American Rivers. A smaller one-man seine, about three feet square, mounted between two poles had also proved effective for capturing fish that were concentrated under overhanging banks or in small pockets in the brush close to shore. Unlike the fyke nets, the seines sampled almost all the sizes of salmon

fingerlings present in the river at the time. Salmon collected by seining were usually unharmed by the operation.

A few salmon had been trapped at night by using a light and a hoop net during the testing of electric fish screens at Mendota on the San Joaquin River. This net consisted of an iron ring three feet in diameter on which a bag of one-half inch stretched mesh netting had been laced. Heavy twine attached to three points on the ring formed a bridle for lifting the net. This device was lowered from the end of a pier and fished about two feet under the water surface. A spotlight directed on the water attracted young salmon. When a school had accumulated, the light was slowly dimmed. This had the effect of concentrating the fish closer to the light. The net was then raised quickly. Salmon caught in this manner were in excellent condition since it took only a matter of seconds to pull up the net and empty any fish caught into a container. This gear required the constant attention of one or preferably two men and was rendered much less effective by windy or stormy weather or by muddy water.

Fishing Methods Tried on the Sacramento River

Seining seemed a logical method to try first on the Sacramento River. Red Bluff was selected as the site of operations. This locality was upstream from the main tributaries of the Sacramento River and most of the salmon caught here would be natives of the main stream. This site was also close to Coleman Hatchery where the fish were to be hauled for marking. The area is shown in Figure 1.

Seining started on February 1, 1950, but was discontinued a week later. During this week, only 400 salmon had been taken by a crew of six men using seines of various lengths. A number of difficulties were encountered which made it impossible to use seines with any degree of success. The bottom of the Sacramento River was far rougher than that of the Tuolumne and American Rivers where seining had previously been successful. Seine hauls could not be made without snagging the lead line on the rubble and boulders in the stream bed, and most of the salmon made their escape while the lead lines were being freed. There were very few bays, pockets or side channels where seines could be used effectively. The bottom was so rough that the maximum life of a fine-meshed seine was only a few hours.

Attempts were made at night to trap salmon by suspending a light over a submerged hoop net as previously described. The net was fished off an old ear ferry tied up at Red Bluff. This method of trapping fish was abandoned after a few nights when it became evident that the catch would not exceed 10 to 20 salmon per hour.

On February 5, 1950, two riffle fyke nets were set out for a night's fishing at the downstream end of a shallow riffle near Red Bluff. They were placed in a current that seemed to be swift enough to trap fish and yet not kill them. The results of the night's fishing were gratifying; there was a catch of more than 1,200 live salmon in the two nets. These fish were small, averaging about 40 mm. (slightly over $1\frac{1}{2}$ inches) in length; however, they were large enough to mark successfully. From this test it appeared that by fishing a number of fyke nets, it would be possible to obtain the required salmon for marking in a reasonably short time.

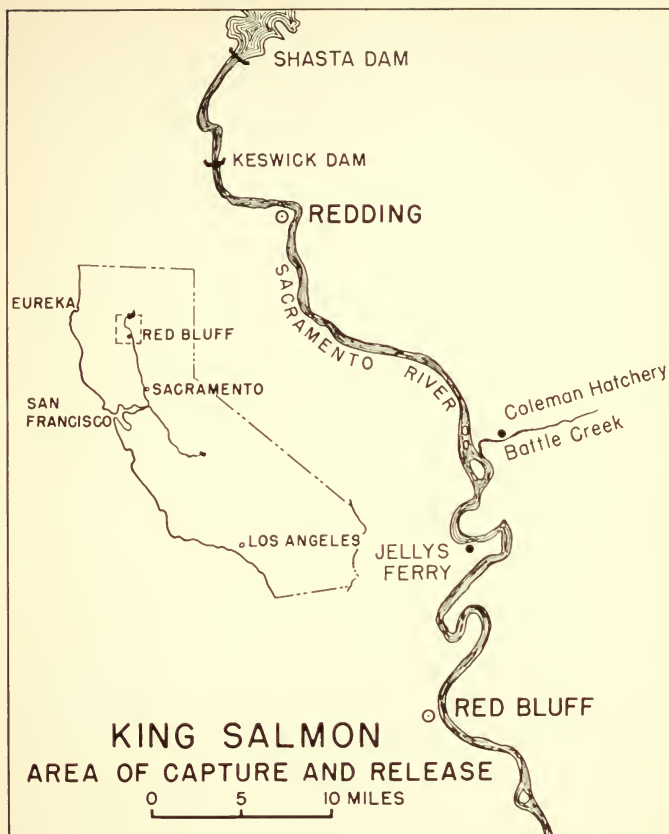


FIGURE 1. Map of the portion of the Upper Sacramento River where king salmon were trapped, marked and released

Use of Fyke Nets

Construction of Nets

Work was begun at once on 20 more riffle-type fyke nets of the design shown in Figure 2. The nets were made of one-half inch stretched mesh, six-thread cotton webbing. This mesh size allowed the smallest fish to pass through the net and escape, but finer material would not hold up in a current for any length of time, and the fish which did escape were, in general, too small to be suitable for marking. A sock or cone was formed first by sewing together the sides of a piece of webbing 300 meshes deep. The sock was 560 meshes in circumference on one end and tapered



FIGURE 2. Fyke net of the type used to capture wild king salmon fingerlings for marking. Note the handles and the legs. The handles make it much easier to wrestle the net in midstream. The legs serve to keep the webbing from chafing on the bottom and result in its lasting several times as long.
Photograph by R. J. Hallock.

to 320 meshes in circumference at the other end. The large open end of the sock was hung on a three- by five-foot rectangular frame of three-fourths inch galvanized pipe. The pot of the net where the fish were collected was formed by closing the small opening in the sock with a puckering string. The fyke funnel of webbing tapered to a six-inch by eight-inch rectangular opening, and was installed inside the sock 120 meshes back of the pipe frame. This funnel enabled the fish to enter the net and prevented their escape once they were trapped.

To hold the shape of the net, two additional rectangular frames were constructed of three-eighths inch round iron. One, 29 inches by 48 inches, was hung on the outside of the sock at the point where the funnel had been sewed in. The other, 22 inches by 34 inches, gave support to the pot

100 meshes from the puckered end of the net. Handles were welded to the top corners of these iron rectangles for ease in pulling the nets. Six-inch legs were attached to the pipe frame as well as to the smaller frames to keep the webbing from chafing on the stream bed. A bridle of five-eighths inch rope attached to the pipe frame completed the net. Using assembly line methods, 20 nets were finished and treated with copper naphthanate preservative in eight days by a six-man crew.

Placement of Nets

Finding suitable locations to fish 20 additional nets was more of a problem than had been anticipated. At first the nets were strung out in a line parallel to shore on a series of riffles near Red Bluff. Each net was fished at the end of a length of eight gauge galvanized wire (0.165-inch diameter) which had been attached to an overhanging tree or to a metal stake driven into the stream bed. The distance each net was placed from shore was governed by the depth and velocity of the water. Sufficient debris accumulated inside the nets to kill the catch if this trash were churned around by a fast current. A flow just swift enough to keep the nets stretched out and a depth of two and one-half to three and one-half feet produced the greatest catches of live salmon. Fortunately there was relatively little fluctuation in water level to complicate the fyke netting. The river flow past Red Bluff varied little from 5,000 cubic feet per second while fyke nets were being fished.

The numbers of fish taken by different nets varied greatly. Nets in locations where catches were consistently poor were moved to new sites. Oddly enough, when several nets were fished only a few yards apart in a line parallel to shore, the net farthest downstream often made a larger haul than nets immediately above it.

After more than a week of changing netting sites, an ideal riffle was discovered about one mile downstream from the 99-E highway bridge over the Sacramento River at Red Bluff. Here the stream possessed a regular cross section with a depth which did not vary greatly from three feet, and it was possible to fish all the nets side by side at right angles to the shore. The row of 22 nets extended from shore to midstream. Part of the nets on this riffle are shown in Figure 3A.

Tests showed that seaward migrant salmon moved mainly at night in this area. Accordingly, the fyke nets were placed in the water near evening and left in position until the following day. Each morning the nets were brought ashore, one at a time, by a three-man crew. Heavy rubber waist waders proved invaluable to these men since the water was too deep for hip boots and it was not practical to use a boat for servicing nets in riffle areas.

As soon as a net was landed on the bank, the puckering string was released. The contents of the pot was then emptied into a tub of water, and all debris removed by hand (Figures 3B and C). Species other than king salmon were returned to the river. The salmon were then placed in aerated 12-gallon cans. The empty net was carried back into the river where it was washed. After cleaning, each net was stretched between trees on the bank for drying and mending.



FIGURE 3. Fyke netting for king salmon fingerlings in the Sacramento River near Red Bluff, California. A—Part of the line of fyke nets. B—Emptying net into a washtub. C—Sorting out the trash. A gallon of trash to a pint of fish is a crude estimate of the usual ratio. Photographs by George H. Warner.

Since king salmon were the only salmonoids captured in the nets, sorting out other species was not difficult. The principal fishes other than the salmon were suckers (*Catostomus*), catfish (*Ameiurus*), Sacramento squawfish (*Ptychocheilus*), ruffle sculpins (*Cottus*), and bluegills (*Lepomis*). Steelhead trout (*Salmo gairdneri*) were not a problem. The fish of the year had not yet hatched, and the yearlings were too large and active to be taken.

Catches of the Fyke Nets

Between February 14 and March 10, 1950 (25 days), the 22 fyke nets captured 227,000 live salmon, an average of a little over 9,000 per day. However, at the time that marking was completed, between 15,000 and 20,000 live salmon were being trapped each day. The U. S. Fish & Wildlife Service was using a fyke net to sample the seaward migration of king salmon past Balls Ferry on the Sacramento River, and contributed 14,000 live fish for marking.

Selectivity of the fyke nets was very high since fishing was conducted in only moderately fast water to insure a live catch. Throughout the program, the average total length of salmon caught varied only slightly from 41 mm. Numerous salmon up to five or six inches in length could be observed feeding around the nets every morning and evening, yet these fish never appeared in the catches. Many small salmon just out of the gravel escaped from the nets. These small fish could be seen wiggling through the meshes while the nets were being carried from their fishing position to shore. Their loss was of little importance since they were too small to mark successfully.

Transporting the Catch

As soon as a milk can was filled with live salmon (up to 2,000 per can), it was placed in a two-wheeled box trailer. This metal trailer could accommodate 12 cans in addition to aeration equipment. A single cylinder air compressor turned by a three-fourths horsepower gasoline engine supplied air to each can through lengths of rubber tubing. Air was forced through a porous stone at the end of each piece of tubing, breaking the air stream into fine bubbles for greater oxygenation of the water. Since there were no roads in the area where the nets were located, a Jeep was used to pull the trailer cross-country over rough terrain to the river's edge. With this equipment, as many as 20,000 young salmon were hauled at one time some 27 miles to Coleman Hatchery. Marked salmon to be released were taken back to the river in this trailer. The same trailer with only six cans was later used to transport silver salmon. It is shown in Figure 5F being loaded with silvers.

Time Spent at the Hatchery

Wild salmon were marked as they were brought in to make their stay at the hatchery as short as possible. They remained at the hatchery until the mortality caused by marking was no longer evident. The time spent at the hatchery by an individual day's catch averaged about three days with a minimum of two days and a maximum stay of 10 days for one small group captured before marking actually got under way.

While at the hatchery, wild salmon were offered food at the same time the hatchery fish were fed. Some wild fish started eating on the day of arrival. Those remaining at the hatchery three days were almost all feeding but ate less than hatchery fish. Many wild salmon fed immediately after fin clipping, especially if they had been in the hatchery troughs for a day before marking.

Movement of Marked Kings in Sacramento River

When marked wild king salmon were returned to the Sacramento River, they moved rapidly downstream from the release point. These fish were set free at Jelly's Ferry, about 15 miles upstream from Red Bluff. Jelly's Ferry was selected as a planting site as it was the nearest place to the fyke net area where a surfaced road led directly to the river's edge. The first group of 5,704 marked kings was released on February 17th at about 2 p.m. The next morning, six of these fish were captured in the fyke nets at Red Bluff. No attempt was made to determine whether or not there was any migration other than towards the sea.

CAPTURING SILVER SALMON

California has no hatcheries devoted to raising silver salmon, although small quantities of these fish are occasionally reared at Prairie Creek Hatchery. No silver salmon were available at this hatchery in 1951; consequently, the fish to be marked had to be obtained from some of the coastal streams where silver salmon runs occur. Since Prairie Creek Hatchery afforded facilities for fish marking and a number of streams in the vicinity were known to contain silvers, operations were conducted in this area.

Capturing wild silvers in small streams was a far different problem than trapping migrating king salmon in the Sacramento River. Unlike most kings, silver salmon remain in fresh water during their first year, and move into the ocean in the spring of their second year. The capture of yearling silvers was greatly to be preferred because these fish could be directly compared with hatchery yearlings released by the other states, and would be past the period of greatest mortality.

The possibility of trapping yearling silvers as they migrated past Benbow Dam on the Eel River was considered. A survey of the site indicated that the heavy spring run-off would make it difficult or impossible to install and maintain any trapping device large enough to capture the numbers needed.

Plans were then made to capture the fish in smaller streams farther north. It was realized that this change would probably give us adequate numbers of fish of the year but would not provide enough of the more desirable yearlings. Unfortunately, no other procedure seemed likely to do any better. Provision had already been made to use one mark on 1949 brood year fish (yearlings) and another on fish of the year (1950 brood year).

Testing Different Fishing Methods

Several methods of obtaining young silver salmon were tested in Prairie Creek. Riffle fyke nets, never seriously considered for the project, proved worthless since the fish were not migrating. The few fish trapped were probably caught as they moved around on riffles in search of food. Once in a fyke net, they seemed much less hardy than the king salmon trapped in the Sacramento River. Even at low flows, silvers would not survive if left in the net all night.

A one-man electric fish shocker apparently effective in some small streams was assembled for testing. This equipment was patterned after a shocker described by Morris (1950, pp. 39-42) and used by him with success. The device consisted of a six-volt hot shot battery and a model T Ford coil which were carried in a knapsack on the operator's back. Copper electrodes mounted on the ends of two eight-foot bamboo poles were connected to the battery and coil with flexible insulated wire. The operator grasped a pole in each hand, and with the electrodes about four feet apart, pushed them ahead of him in the stream. Fish swimming between the electrodes were supposed to be temporarily stunned so they could either be dipped up in a seap net or collected in a seine stretched across the stream below the shocker. This outfit was not successful in paralyzing large numbers of small silver salmon in Prairie Creek. If the distance between the electrodes was decreased to about 18 inches, a salmon directly between them would either be stunned or show distress, but if the fish was in any other

position, it would show no indication of feeling the current. Bio-electrical experiments have a way of consuming much time so we retired the device instead of attempting to modify it.

Seines were tried in Prairie Creek and it was demonstrated that young silver salmon could be taken in fairly good numbers by this means. Seining, then, seemed to be the most practical way to obtain fish in the quantity needed for marking.

Seining Fingerling Silver Salmon

Construction of Seines and Other Equipment

A variety of seines were constructed ranging from a three-foot square one-man type to a 40-foot two-man style. Seines 10 to 20 feet long by six feet deep proved more useful than the larger nets. Tests showed that cork floats three inches in diameter and spaced 12 inches apart were sufficient to hold up the seine, and two ounce leads spaced eight inches apart made a satisfactory lead line. A five-foot pole on each end of the net made seining easier.

Japanese cotton netting one-half inch stretched mesh, 20/6 cable laid twine, was found to make a light seine, easy to pull even in a fast current. However, sharp rocks and snags ruined this netting in short order. One-half inch stretched mesh webbing of six-thread medium-laid seine-twine made a more durable net, although it was heavier and harder to pull through the water. At best the webbing lasted only a few days, and it was necessary to keep one man engaged solely in turning out new seines in order to have replacements available as needed.

The first seines were treated with copper naphthanate to lengthen their lives. This was found to be an unnecessary precaution since the nets were worn out from hard use long before they would become weakened by rotting. The white, untreated nets frightened fish more than nets that had been dyed green with copper naphthanate. This tended to keep fish ahead of the white seine and fewer fish escaped by dodging under the lead line.

Other equipment was necessary in carrying out the seining program. Lives boxes were essential to hold fish until the end of the day when they could be picked up and hauled to the hatchery. These boxes were made of hardware cloth fastened to a wooden frame, and were constructed in sets of five. The largest measured two feet high, three feet wide, and four feet long. Four other progressively smaller boxes nested inside the largest box for ease in transportation.

Several three- and four-gallon buckets were used by a seining crew to collect fish and transport them to the closest live box. Two hundred silver salmon could be handled in a bucket if the trip to a live box was reasonably short.

Waist waders for each member of a seining crew were indispensable. There was very little area in any of the streams covered that could not be seined by men wearing these waders.

Young silver salmon were transported from streams to the hatchery in the same trailers that were used on the Sacramento River in 1950. A Jeep was essential in getting the trailer into some of the areas where old logging roads, or no roads at all, made travel with an ordinary vehicle impossible.

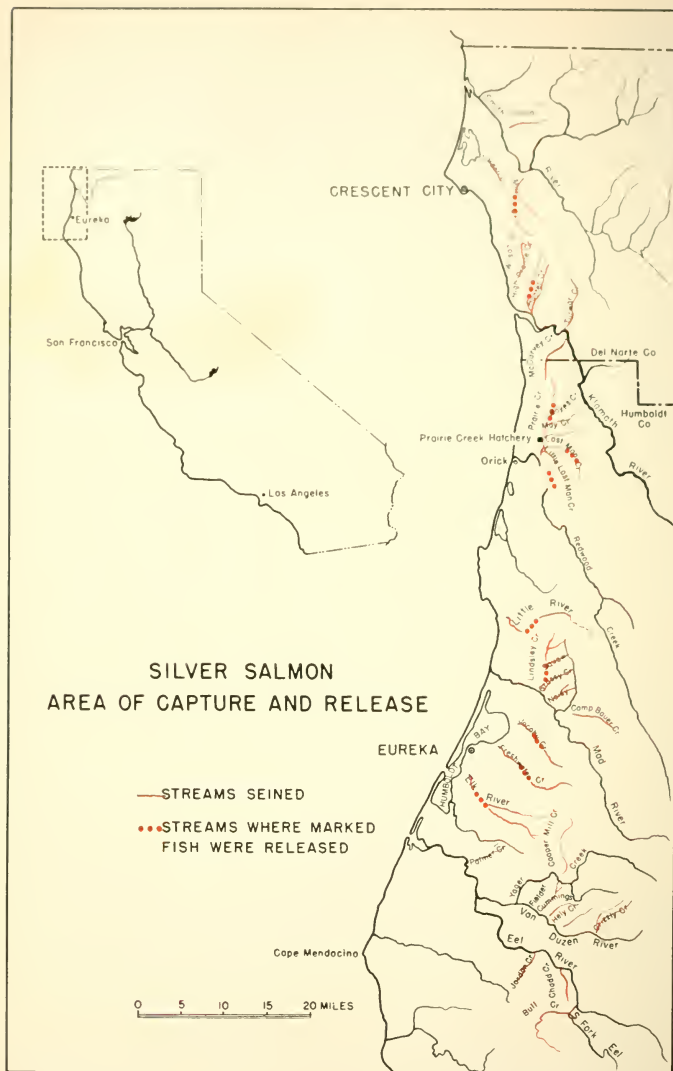


FIGURE 4. Map of the area where silver salmon were seined, marked and released.

Area Seined (Figure 4)

Seining for silver salmon was confined to the coastal streams of Humboldt and Del Norte Counties, between Bull Creek, a tributary to Eel River, and Mill Creek, a tributary to Smith River. Very few salmon were taken south of Humboldt Bay because of the long hauling distance to Prairie Creek Hatchery. All releases of marked fish were made in permanent streams between Elk River, a tributary to Humboldt Bay, and Mill Creek in Del Norte County.

Seining Procedure (Figure 5)

Before a seining crew worked a stream, a man was sent ahead to scout the area. He first determined if young silver salmon were present by making hauls with a one-man seine at various places along the stream. Then on a county map, he marked the access roads, if any, and obtained the landowner's permission if it were necessary to use private roads, or to trespass on private property. By contacting local state fish and game wardens for information, the scout often saved much time in locating streams and roads.

If the scout's report was favorable, a seining crew moved into the designated area, placed live boxes at about 400-yard intervals along the selected stream and started seining. Five live boxes per crew were usually sufficient for a day's netting. During most of the operation, it was possible to keep two seining crews in the field. At times, these crews worked different streams, but often they covered different sections of the same stream.

The seining procedure did not follow a definite pattern. In most streams, the current was not strong enough to collapse a seine even when it was pulled downstream. Usually the seiners looked over a pool to decide where a net could be best landed or beached, and the seine was worked in that direction. Several seines of different lengths were carried by each crew, and the choice of net was governed by the size of a pool to be seined. The physical characteristics of the stream limited the effectiveness of the seine more than did the wariness of the fish. Many young silvers made no attempt to avoid the net; others even swam out from inaccessible places to see what was going on and were collected in the seine.

A three- or four-man crew could effectively seine most streams. On a stream where fish were not too plentiful, two men would pull a seine and a third man would carry buckets of fish to the nearest live box as the seiners worked from pool to pool past each box in turn. In waters where salmon were more concentrated, it was desirable to have two men shuttling buckets between the seiners and the live boxes.

Proper placement of each live box in the stream was important in keeping the fish alive. Quiet water with only a slight current kept fish in the best condition. Twice, live boxes were located in places where water currents proved to be too strong. In a short while the salmon became tired from swimming against the stream and were plastered against the downstream side of the box. Each time this was quickly discovered and the box moved.

On several streams, it was not possible to pull a trailer close to all the live boxes in a stream. In such places, a "bucket brigade" was formed



FIGURE 5. Seining silver salmon for marking. A—A one-man seine as used in small pockets under banks, etc. B—A two-man seine in operation. The men had little trouble herding silver salmon across large pools with nets which seemed much too small for the job. C—Beaching a two-man seine. A second seine crew has just appeared, and on this occasion the two groups will combine forces to transport their catches to the hatchery for marking. D—Sorting the catch. In this stream only silver salmon and trout were present. E—Pouring a bucket of fish into the live box. F—Loading fish onto the trailer for transportation to the hatchery. The gasoline-powered aerator pump can be seen at the forward end of the trailer. Photographs by D. H. Fry, Jr., and R. J. Hallack.

to move the fish from live box to live box until all salmon were concentrated in the one box closest to the Jeep and trailer. From here, bucket carriers worked at top speed to move the catch to the trailer. The trailer is shown in Figure 5F.

The Catch

Seining was started on May 8th and concluded on July 20, 1951, when a total of 168,362 silvers had been captured. During this period, 56 days were spent in seining for an average catch of 3,000 salmon per day. The maximum day's catch was slightly over 9,000 fish.

Most yearling silvers appearing in the catch were taken early in May near the mouths of streams. They represented the last of the seaward migrant yearlings still in fresh water. A few yearlings that had become trapped in drying streams and potholes were netted throughout the seining program.

Sorting silver salmon from the variety of species captured in the seines took time. When seining was done on a stream with a permanent flow, much of this sorting was done by the seiners (Figure 5D). After each haul of a net, the silver salmon were picked out and placed in a pail. The remainder of the catch was set free. However, much of the seining was done in small streams which were going dry, and all fish captured were transported to the hatchery for sorting. The trout and king salmon were released with the marked silver salmon in suitable streams. The principal fishes captured in addition to silver salmon were king salmon, steelhead trout (*Salmo gairdneri*), coastal cutthroat trout (*Salmo clarki*), sculpins (*Cottus*), and suckers (*Catostomus*). A few green sunfish (*Lepomis cyanellus*) were also captured in Turwar Creek, a tributary to the Klamath River.

Over 48,000 of the silvers marked were saved from certain death in drying streams. At least twice this number of steelhead and cutthroat trout were transferred to permanent waters as a result of the silver seining. In one day alone, June 25, 1951, approximately 24,000 trout and 2,000 silver salmon were rescued on Wilson Creek in Del Norte County.

Silver Salmon at the Hatchery

Each daily catch of silver salmon brought to the hatchery remained there about two days. Marking was usually done on the first day, but marked fish were held an additional day to observe the effects of marking and handling. While at the hatchery, wild silvers were offered food at the same time that hatchery raised fish were fed. A few silvers took food during their first day in the troughs, and by the second day, many fish were feeding, but not so voraciously as hatchery fish. The yearling silvers ate but little even after several days. As a whole, the silvers did not appear to adapt themselves to hatchery life as readily as the king salmon captured in the Sacramento River in 1950.

Movement of Marked Silver Salmon in Streams

The marked silver salmon spread rapidly when returned to a stream. On the North Fork of Elk River, a tributary to Humboldt Bay, 1,572 silvers were released late one morning and 47 were recaptured a mile

upstream the next day. On the South Fork of Elk River, 3,856 silvers were released about 10 a.m., only to appear in the seines about three-fourths of a mile downstream at 3 p.m. the same day. The majority of the fish released in Prairie Creek, Humboldt County, were planted at the south end of the Prairie Creek State Park campgrounds. Some of these fish were captured in seines about three miles upstream from this release point, three days after the initial planting. This same rapid movement of marked silvers, in both directions from the release point, was noted in Mill Creek, in Del Norte County, where the fish distributed themselves fairly evenly along the upper lengths of the stream in a short time. The better producing streams were seined more than once, and this self-distribution by the silvers was so rapid and so complete that careful planning was necessary to avoid recapturing many marked fish.

Test hauls were made on several streams where marked fish had been released. This was done to learn if it was still possible to seine without recapturing large quantities of marked fish. On sections of Mill Creek, the seine hauls captured silvers of which an estimated one-third to one-



FIGURE 6. Women markers clipping fingerling salmon at Prairie Creek Hatchery. A larger crew was used at the Coleman hatchery. Photographs by D. H. Fry, Jr.



FIGURE 7. Closeup of a woman marker with a scap net; fingerling king salmon in front of her. Note the hand tally near the lower left corner of the picture. Photograph by D. H. Fry, Jr.

half were marked. In Prairie Creek on June 13, 1951, a total of 2,039 silver salmon were taken of which 442 were already marked.

Other test hauls were made in Mill Creek and Prairie Creek during the latter part of the marking period to observe the condition of the fish. There was no sign of any infection and the fin scars seemed entirely satisfactory.

MARKING KING AND SILVER SALMON

Both at Coleman and Prairie Creek Hatcheries, practically all of the fin clipping during these first two years was done by women hired as seasonal employees. Most were housewives living in the vicinity of the hatcheries. Whenever possible, local residents were hired so that in succeeding years, the likelihood of obtaining experienced employees would be increased.

Women become quite adept as markers. Fin clipping requires a nimbleness of fingers which many men do not have. It also requires perseverance and excellent eyes.

Each marker wore a special glove made of bobbinet. This covered the thumb and first two fingers of the hand used to hold the fish. The women made these gloves themselves. Fins were removed with a five-inch flat-jawed stainless steel clipper of a type known as nail-splitting forceps. A hand tally mounted on the trough beside each marker enabled her to keep count of the fish clipped. (See Figures 6, 7, 8, and 9.)



FIGURE 8. Clipping a ventral fin from a wild silver salmon fingerling. Note the bobbinet glove covering the thumb and two fingers of the marker. Photograph by D. H. Fry, Jr.

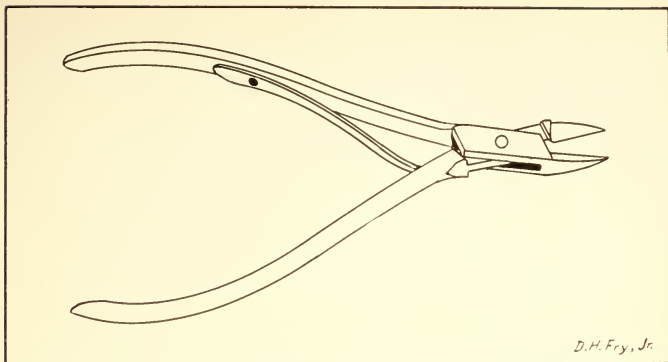


FIGURE 9. Clippers used for marking salmon. About two-thirds actual size. These tools are known to the surgical supply trade as nail-splitting forceps.

Numbers of Salmon Marked

During 1950 and 1951, California marked 860,917 salmon. Of these, 845,469 were released. Mortality from all causes after marking was 15,448 or about 1.8 percent. Of those marked and released, 444,026 were hatchery-raised king salmon and 235,248 were king salmon captured in the Sacramento River. In addition, 166,195 silver salmon captured in the streams of Humboldt and Del Norte Counties were marked and released. Table 1 gives a summary of the first two years of marking.

Hatchery-reared Salmon

The 235,466 hatchery-raised king salmon released in Battle Creek in the spring of 1950 were the progeny of the 1949 fall run, trapped and spawned artificially at Coleman Hatchery on Battle Creek. This group of fish was furnished for marking by the U. S. Fish and Wildlife Service. These hatchery-reared salmon were marked at Coleman Hatchery by the same crew and during the same period that salmon brought in from the Sacramento River were being marked. Hatchery fish were marked whenever all available wild salmon had been fin clipped. This procedure decreased the time spent at the hatchery by wild kings, but it increased the period of marking for hatchery fish. After marking, hatchery-reared fingerlings were held in outside ponds until they were released in a group on March 31st. They averaged 44 mm. in total length when marking started, but the mean had increased to 56 mm. by the time the last group was marked. Eighty percent of the fish were marked during the last 11 days. During this period, the mean increased from 52 mm. to 56 mm. total length. The mean of the entire group at time of marking was 53 mm. (slightly over two inches).

An additional 132,734 hatchery-raised king salmon were marked and released in the spring of 1950. These salmon were hatched from eggs spawned artificially at Sweasey Dam on Mad River in the fall of 1949 (1949 brood year). They were reared at Prairie Creek Hatchery where

the marking was done. The fish were planted between May 4th and May 18th in Big River in Mendocino County where the Department of Fish and Game is attempting to establish a run of king salmon. The fish averaged 43 mm. in total length when marked (slightly under 1 $\frac{3}{4}$ inches).

For a marking experiment, it would have been far better to have planted the marked fish in Mad River since that stream produced the eggs. However, the department was already committed to stocking Big River and the egg take had been so poor that there were not enough fingerlings for both plants.

In the spring of 1951, a group of 75,826 hatchery-raised king salmon were marked at Prairie Creek Hatchery and placed in Mad River. Only the left ventral fin was excised on each of these fish. This work was done as one of a series of hatchery survival experiments being conducted by the Bureau of Fish Conservation. It was not part of the Pacific Marine Fisheries Commission experiment, but the actual marking was done by the same workers. These fish were the young from the 1950 fall run (1950 brood year) in Mad River, spawned artificially at Sweasey Dam. Marking was completed on June 19th; however, the fish were not released until the latter part of July and the early part of August. On June 15th, 300 of the marked salmon were measured, giving an average total length of 66 mm. and a range of 55 to 78 mm.

Marked Wild Salmon

Three groups of salmon captured in streams were marked and released in 1950 and 1951.

The 235,248 king salmon captured and released in the Sacramento River near Red Bluff in February and March of 1950 were the offspring of salmon which spawned in the fall of 1949. All or nearly all of them were fall-run fish. There is little possibility that many were the progeny of the 1949 spring run. The Sacramento spring run adults spawn earlier than fall-run fish and there are usually two peaks in the seaward migration of the young. The first and smaller peak is presumed to consist of spring-run fish. Fyke netting for young kings was not started until the middle of February, and undoubtedly all but the end of the spring run had passed Red Bluff. The small and remarkably uniform size of the salmon captured would strengthen the belief that the somewhat older spring-run fish were not present in any number. All salmon were hauled to Coleman Hatchery for marking, and were later released in the Sacramento River at Jelly's Ferry. Fingerlings from 14 different daily catches were measured in lots of 50 each, with each group varying only slightly from 41 mm. in average total length.

In 1951, two age groups of silver salmon were seined in the smaller coastal streams of Humboldt and Del Norte Counties. One hundred sixty-four thousand four hundred twenty-three silvers were the young of the 1950 brood year, and 1,772 were yearlings or the progeny of the 1949 brood year. All silvers were marked at Prairie Creek Hatchery and returned to the streams within three days. All marked silvers were placed in streams between Elk River, a tributary to Humboldt Bay, and Mill Creek, a tributary to Smith River. Table 2 shows the numbers of silvers seined from each stream, and marked fish returned. The majority of those streams from which salmon were seined and not returned, were streams which usually went dry during summer months. Others, such as

TABLE 2

Silver Salmon Seined and Released in the Streams of Humboldt and Del Norte Counties, May-July, 1951

Stream	County	Salmon taken from each stream		Marked salmon released in each stream	
		Yearlings (1949 brood yr.)	Fish of the yr. (1950 brood yr.)	Yearlings (1949 brood yr.)	Fish of the yr. (1950 brood yr.)
High Prairie Creek	Del Norte	166	3,371		3,813
Hunter Creek	Del Norte	35	500		
Jaqua Creek	Del Norte		25		
Jordan Creek	Del Norte		200		
McGarvey Creek	Del Norte	20	200		
Mill Creek	Del Norte	71	60,531	184	68,790
Turwar Creek	Del Norte	50	3,000		
Wilson Creek	Del Norte	833	10,531		
Boyes Creek	Humboldt		240		
Bull Creek	Humboldt		3,000		
Camp Bauer Creek	Humboldt		200		
Chadd Creek	Humboldt		500		
Cooper Mill Creek	Humboldt		216		
Cummings Creek	Humboldt	2	500		
Elk River	Humboldt		17,671	44	8,591
Fielder Creek	Humboldt		2,100		
Freshwater Creek	Humboldt	2	8,640	7	1,391
Grassy Creek	Humboldt	45	11,158		
Grizzly Creek	Humboldt		500		
Hely Creek	Humboldt		200		
Jacoby Creek	Humboldt	20	14,223		13,021
Jordan Creek	Humboldt		500		
Lindsey Creek	Humboldt	80	10,583		16,518
Little Lost Man Creek	Humboldt		189		
Little River	Humboldt		813	5	2,212
Lost Man Creek	Humboldt	20	1,500	258	9,252
May Creek	Humboldt		300		
Noisey Creek	Humboldt		500		
Palmer Creek	Humboldt		956		
Prairie Creek	Humboldt	430	6,931	1,232	30,786
Redwood Creek	Humboldt			42	10,049
Squaw Creek	Humboldt	10	6,800		
		1,784	166,578	1,772	164,423

Bull Creek and Freshwater Creek, showed signs of pollution in sections below communities, and were not replanted except in localities remote from the polluted area. This accounts in part for a smaller number of salmon being returned to some streams than was taken out for marking. Little River and Redwood Creek are both excellent silver salmon streams, but were not seined extensively because in the few places where they could be reached by road, the pools were so deep as to make netting impractical. However, these streams made good planting places and as such received more fish than were taken from them.

The relatively few yearling silvers fell into two size groups: The larger fish were captured in May close to the ocean. Apparently, they were about to enter salt water. An even 1,000 of these fish were marked, most of them from Wilson Creek. A sample of 25 of these fish had a range of 144 to 177 mm. with a mean of 149 mm. total length (5½ inches).

The smaller yearlings were taken throughout the seining operations, usually in an isolated section of a stream or in some other place from

which low flows had made it difficult or impossible for them to reach the ocean. Eighty-two were measured and they ranged from 90 to 132 mm. with a mean of 99 mm. A total of 772 of the smaller yearlings were marked.

The 1950 brood-year fish increased in size throughout the period of marking (May 14 to July 21, 1951). Early in June, 242 were measured and showed a range of 40 to 88 mm. (mean 52 mm. total length). By the end of the marking period, the fastest growing fish of the year were a few millimeters longer than some of the stunted yearlings which had been trapped in drying sections of the streams. There was no overlap between the two year classes in any one stream.

Mortality Due to Marking and Related Causes

During 1950-1951, the California Department of Fish and Game marked 860,917 salmon. Mortality from all causes after marking such as disease, direct effects of marking and handling, was 15,448 or 1.8 percent. During the period of marking, over 4,000 marked fish and unmarked controls were set aside in lots of 500. These groups were held from four days to two months. Observation of these groups showed that most of the mortality which could be attributed to handling and marking occurred during the first 24 to 36 hours after clipping. As a result of these observations, all wild fish were held at least 36 hours after marking. Hatchery fish were held much longer.

Speed and Accuracy of Marking—Fin Regeneration

Experience of many markers in many previous experiments has shown that if fins are not properly removed, they will grow back or regenerate. Two important factors are the size of the fish and the completeness of the excision. The smallest fish not only show the greatest tendencies toward fin regeneration, but they are also the most difficult to mark cleanly.

Marking must be done with great care in order to minimize regeneration, and care is the factor which should be stressed with the marking crew. Speed must also be considered—particularly when there are hundreds of thousands of fish to be marked.

Table 3 shows the different groups of salmon marked during 1950 and 1951, and the average time taken to mark each group. For the entire 860,917 salmon fin clipped, the average number marked by each marker for an eight-hour day was 1,577 or 197 for each hour.

The greatest speed in marking was displayed at Prairie Creek Hatchery where 79,341 fish were fin clipped at an average rate of 230 per hour for each marker. These fish were comparatively large and this was the only lot from which only a single fin was removed. A close second in speed of marking was the fin clipping at Coleman Hatchery in 1950 where two groups (wild kings plus hatchery kings) totaling 475,818 were marked at an average rate of 225 per hour by each marker. Two fins were removed from fish marked at Coleman Hatchery. Only one lot of fish showed possible ill effects from excessive speed in marking. The wild king salmon averaged only 41 mm. in length when marked, yet they were fin clipped at approximately the same rate as fish averaging 12 mm. longer. The

TABLE 3
Marked Salmon Sampling, for Correctness of Marks, at the Time of Marking

Year marked	Species	Brood year	Average total length	Fins removed	Where marked	Number marked	Number sampled	Number with all marks acceptable	Percentage with all marks acceptable	Average number marked per hour
1950	King (captured)	1949	41 mm.	Dorsal and left ventral	Coleman Station	237,797	2,761	2,697	97.6	245
1950	King (hatchery)	1949	53 mm.	Dorsal and right ventral	Coleman Station	238,021	7,628	7,322	96.1	
1950	King (hatchery)	1949	13 mm.	Anal and left ventral	Prairie Creek Hatchery	137,396	11,157	10,718	93.5	170
1951	King (hatchery)	1950	66 mm.	Left ventral	Prairie Creek Hatchery	79,341	20,012	18,982	94.9	209
1951	Silver (captured-yearling)	1949	124 mm.	Adipose and both ventrals	Prairie Creek Hatchery	1,784	500	500	100.0	195
1951	Silver (captured-fish of the year)	1950	52 mm.	Adipose and right ventral	Prairie Creek Hatchery	166,578	10,133	10,103	99.7	

TABLE 4
Regeneration of Clipped Fins

	Number sampled	Months after marking	Both fin marks recognizable	Ventral fin mark recognizable, Dorsal fin mark not recognizable	Dorsal fin mark recognizable, Ventral fin mark not recognizable	Neither fin mark recognizable
King salmon, 1949 brood year: Wild fish from Sacramento River, 41 mm. mean length when marked	352	11	65.4% (230)	29.8% (105)	1.9% (7)	2.8% (10)
King salmon, 1949 brood year: Hatchery fish (Coleman Hatchery), 50 mm. mean length when measured	398	11	96.0% (382)	1.0% (4)	0.5% (2)	2.5% (10)
Silver salmon, 1950 brood year: Wild fish from Del Norte and Humboldt Counties	278	4½	100.0% (278)	0% (0)	0% (0)	0% (0)

dorsal fins of these captured kings regenerated badly. This is discussed below.

Accuracy of marks rather than speed was emphasized at all times. A system which served to stimulate proper marking was to display from time to time on a bulletin board the results obtained from the sampling of salmon taken from each marker. The number of marked fish sampled and the number which were acceptable were recorded opposite the name of each marker. No mention was made of the total number clipped by each individual. The effect was to have each woman striving to improve the quality of her work.

Inspecting for Correctness of Marks

Fifty-two thousand four hundred ninety-four marked salmon were sampled at the time of marking to find out what percentage of the fish were well enough fin clipped so that there would presumably be little or no regeneration. Table 3 gives the percentage of each group of fish that was judged to be properly clipped. The sampling was usually accomplished by examining an equal number of fish from every marker. In this manner, a check on each person marking fish was also obtained. Occasionally a seap net full of salmon was taken from a grouped lot of marked fish in a hatchery trough. Standards were set up for the sampling so that each person looking over fin-clipped fish would be judging the marks in the same manner. Frequent comparisons of interpretations as to the acceptability of marks were made by individual samplers to insure uniformity in the sampling techniques. Table 3 shows the different groups of fish with the results of sampling for correctness of marks at the time of marking. The percentage of acceptable marks seemed satisfactory but these salmon were so small that some idea of the actual



FIGURE 10. King salmon. An extreme example of dorsal fin regeneration. This fin is slightly smaller than a normal dorsal, looks and feels slightly misshapen, but could easily be missed by even a careful observer. Photograph by D. H. Fry, Jr.

amount of fin regeneration was necessary in order to make a good estimate of the numbers of correctly marked fish released. Table 4 shows the three lots of marked fish set aside for this study and the results of sampling over a period of months. In each case, the number sampled from $4\frac{1}{2}$ to 11 months after marking was the total still living. The greatest fin regeneration was in the dorsal fins of the king salmon captured in the Sacramento River. Eleven months after marking, only two-thirds of the captured fish sampled had dorsal fin marks which were acceptable and

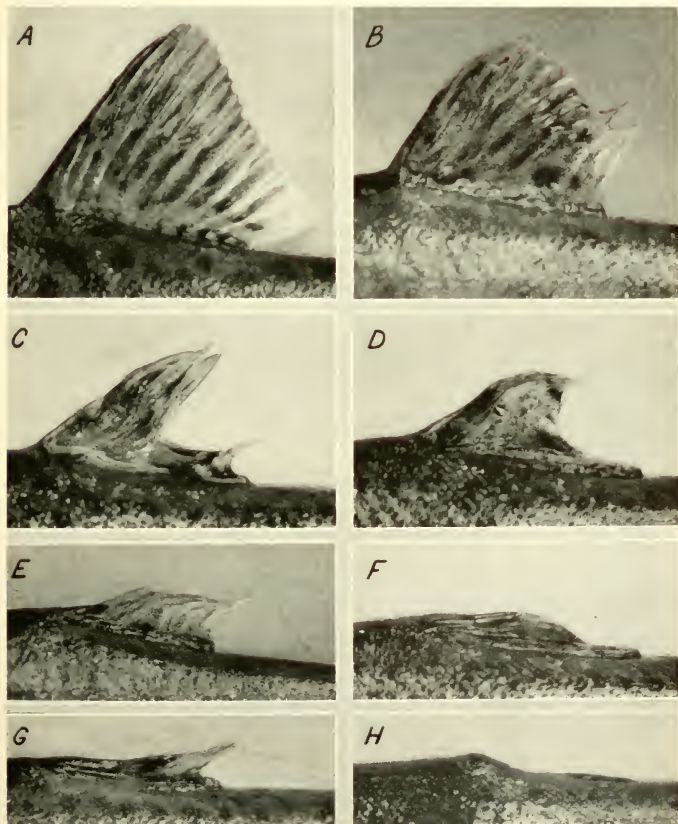


FIGURE 11. King salmon; normal and regenerated dorsal fins. These fish were held at the hatchery for about 10 months, and were about seven inches long when photographed at the end of that time. Most or all of the regeneration had taken place months previously. Trained observers will be inspecting the commercial salmon catch looking for marked fish. A—Normal fin. B—This is as extreme a case of regeneration as a careful observer could possibly detect. C-G—Varying degrees of regeneration. None are apt to pass unnoticed. H—No regeneration. Photographs by D. H. Fry, Jr.



could be positively recognized (Table 4). The hatchery kings also displayed a considerable fin regeneration; however, the regrowth was so incomplete in most instances that it was easy to recognize the fins as having been clipped.

As the king salmon grew, the marks became easier to recognize, but when a sampler looked at a regenerated fin on a six-inch salmon, he realized only too well the futility of trying to guess whether or not another sampler would notice that fin, one, two or three years later while examining hundreds of unmarked fish. This problem applies only to such fins as are shown in Figure 10 and possibly 11B. There should be no trouble identifying the partially regenerated and badly deformed fins such as those shown in Figures 11C to 11G and in Figure 12.

When these marked fish mature, the Sacramento River should be a valuable source of specimens which will be a help in determining more quantitatively just how hard it is for a sampler to recognize fins which have grown back. Any marked 1949 brood-year salmon in the Sacramento will have had the dorsal and one ventral fin clipped, and thus will be positively identifiable if either mark is recognizable.

The problem is actually much less difficult than it would be if the dorsal fins alone were being marked. Each marked dorsal is accompanied by a marked ventral (right or left) and less than 5 percent of the ventral fins seemed apt to be unrecognizable.

It is not known why the regeneration of fins was greatest among wild kings; the only apparent difference between this and the other groups marked was the length of the fish. This may be the only factor of importance and it may not.

Fin regeneration was almost absent on the wild silvers. The small group sampled 4½ months after marking had the most perfectly removed fins of any lot examined. A clipped adipose fin gave no indication of any regeneration, and the ventral fins at most displayed a ray or two of regrowth.

SUMMARY

In 1946, delegates from California, Oregon and Washington formed the Pacific Marine Fisheries Commission to better coordinate fisheries' research and management on the Pacific Coast.

One problem of the commission has been that of the ocean fishery for king and silver salmon (*Oncorhynchus tshawytscha* and *O. kisutch*). Previous work on these two species has included a tagging program engaged in by the three member states and by Canada and Alaska.

California, Oregon and Washington are now engaged in a marking program intended to give quantitative information about the movements of salmon at sea.

It was planned to mark silver salmon in groups of at least 100,000 and king salmon in groups of 200,000 when possible.

California is the only state marking wild (captured) fish.



FIGURE 12. (OPPOSITE PAGE) King salmon; regeneration of ventral fins. The fins have been spread out as far as they would readily open, and pinned in place. Comparison of size and "spreadability" with that of a normal fin makes regenerated ventrals easy to detect. Data as in Figure 11. In each photograph the normal fin is above. TOP: The regenerated fin is somewhat the smaller and could not be spread open like the normal fin. MIDDLE: An even more club-like regenerated fin. BOTTOM: The regenerated fin is no more than a small lump. Completely removed fins were common. Photographs by D. H. Fry, Jr.

In 1950, California used 22 fyke nets to capture king salmon on the Sacramento River. A total of 235,248 wild fish and 235,466 hatchery fish from Coleman Fishery Station were released in this area. Another 132,734 hatchery king salmon from Prairie Creek Hatchery were released in Big River, Mendocino County.

In 1951, wild silver salmon were seined from the coastal streams of Del Norte and Humboldt Counties. A total of 164,423 fish of the year and 1,772 yearlings were marked and released.

Also in 1951, a group of 75,826 hatchery king salmon were marked at Prairie Creek Hatchery and released in Mad River. (This was not part of the Pacific Marine Fisheries Commission experiment.)

All marking of both wild and hatchery fish was done at two hatcheries—Coleman Fishery Station (federal) and Prairie Creek (state).

Women markers were used.

Mortality after marking was 1.8 percent. Most deaths occurred within 36 hours after marking.

The average rate was 197 salmon marked per marker per hour.

Samples of fish from three groups were held to check the extent of fin regeneration.

Dorsal fins of the wild Sacramento kings regenerated badly. About one-third of the fish had dorsals which might not be recognizable if the fish were retaken at sea. Ventral fins of these same fish showed much less regeneration (5 percent possibly unrecognizable). These wild fish were the smallest marked (mean total length 41 mm.). Hatchery kings from Coleman Station (Sacramento River System fish) showed much less regeneration and silver salmon showed almost none.

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REPORT ON EXPERIMENTS DESIGNED TO DETERMINE EFFECTS OF UNDERWATER EXPLOSIONS ON FISH LIFE¹

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INTRODUCTION

In the exploitation of major natural resources conflicts of values and interests often arise. Such a conflict arose when the oil industry, in its effort to meet the increasing demand for its product and to prepare for future needs, undertook seismographic exploration for untapped oil deposits in the rock layers beneath the coastal waters of Southern California. Such exploration requires a point source of intense low-frequency sound and the most practicable generating source is an explosion. Particularly effective and practicable, as explorations in the Gulf of Mexico have demonstrated, is the standard 60 percent gelatine dynamite, which produces a sharp shock wave with an abrupt front of great pressure intensity (Figure 8). Such a wave gives excellent results from the seismographic viewpoint. Unfortunately, however, this type of wave is very injurious to fishes that have an air-bladder, and most of the important food and game species possess this structure. Heavy mortalities of valued fishes resulted from the seismographic studies in the waters of Southern California (Aplin, 1947; Fitch and Young, 1948) and from tests made in Chesapeake Bay (Coker and Hollis, 1950). As a result of the fish killings in California the permits for submarine oil exploration were revoked in 1949, and were not renewed until September, 1951. The renewals were granted after the experiments recounted below had indicated it as probable that black powder would yield usable seismographic data without killing fish in disastrous numbers.

Research to determine the effects of underwater explosions on marine life has been limited. The effects of detonating explosives have received attention by Knight (1907), Gowanloch and McDougall (1944-1946), Aplin (1947), Indrambarya (1949), Gowanloch (1950), and Coker and Hollis (1950), as also in two reports (Anonymous, 1947 and 1948) on the cooperative researches in Chesapeake Bay. We have found no published data on the biological effects of underwater discharges of such relatively slow-burning explosives as black powder.

OBSERVATIONS ON THE EFFECTS OF LARGE CHARGES IN A RESTRICTED REGION

The first set of definite observations made by us to determine effects of underwater explosions on fishes was a by-product of geological experiments conducted by the Scripps Institution of Oceanography in cooperation with the United States Navy. Navy personnel did the firing. The primary object was to determine whether turbidity currents could be induced in submarine canyons by explosions set off at or near the head of the canyon. The tests were conducted in Scripps Submarine Canyon (Shepard, 1949, 1951a, b), immediately north of Scripps Institution, near La Jolla, California (Figure 1). The first trials were run on April 6 and 7, 1950, when ten 50-pound dynamite charges were set off, two near the sandy main head of the canyon at a depth of about 60 feet, two near the middle of this arm at a depth of about 250 feet, and six in the rocky main canyon, near its confluence with Sumner Branch, at depths of about 325 to 350 feet. Large fish kills resulted, but the collection was somewhat incomplete and selective (listed in first column of Table 1). Of the total recorded kill of 1,431 fish, 1,032 were blacksmith and 245 were rockfish of various species (for scientific names see list on page 366).

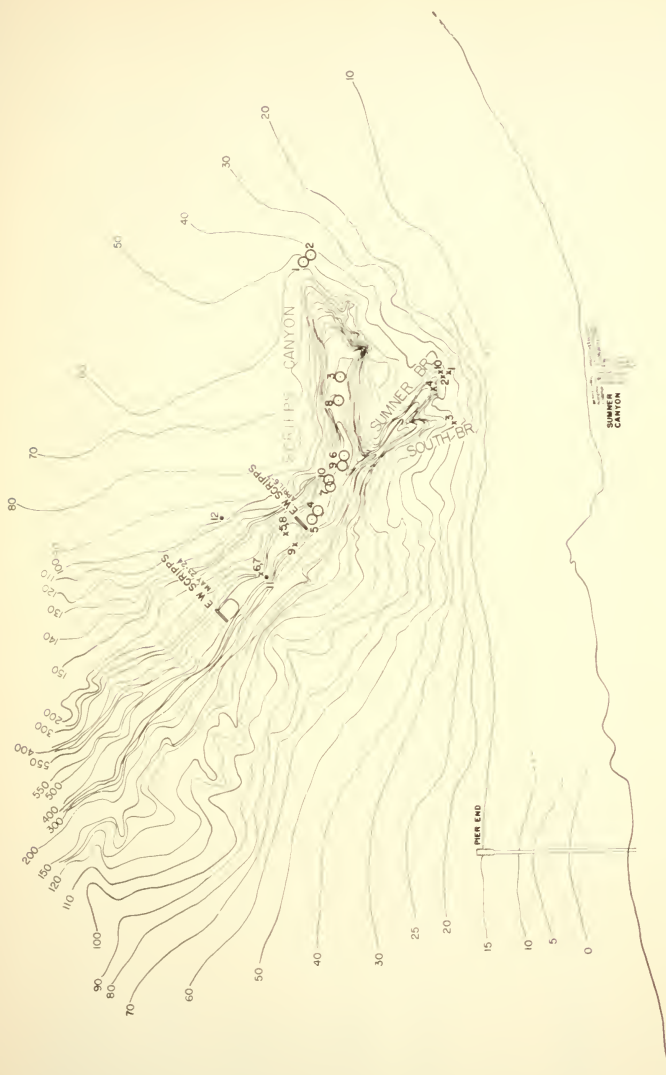


FIGURE 1. Map of Scripps Submarine Canyon, showing location of dynamite explosions of April 6-7 (circles) and May 23-24 (crosses), 1950. See Table 1. The pier is 1,000 feet long. Traced from map provided by Dr. Francis P. Shepard.

TABLE 1
Record of Fish Collected Dead or Dying at Surface After Dynamite Explosions
in Scripps Submarine Canyon, California

For scientific names see p. 366. This plus sign (+) indicates that additional specimens were destroyed but not recovered.

Date (1950).....	Apr. 6-7	May 23										Totals	
		1	2	3	4	5	6-7	8	9	10-11	12-13	May 23	May 24
Blast No. (Figure 1).....	60-350	50	79	55	90	405	430	105	325 ±	60 ±	450 ±	18	9 13
Depth (blast on bottom).....											(6,000)	50-150 *	60-150 *
Time of blast (about).....	1007-1619	0925	1030	1100	1310	1350	1440	1555	1000	1030	1130	0925-1555	1000-1130
Weight of charge, pounds.....	50 or 100	50 or 100	50 or 100	50 or 100	100	50	50+50	100	100	50+50	50(+4)	50-100	50-100(+4)
Pacific sardine.....	1			1				2				3	
Panama bristlenmouth.....	27	53	1	4	3							61	
Kelp bass.....		7										7	
Sand bass.....	29++	2		20		72			10	5	62+	94	77+
Grunion.....	54+	21	8	12	29	7		3			7+	80	7+
Jacksmelt.....		1				9	1	15			5+	26	5+
Kelp topsmelt.....				1								1	
Jack mackerel.....			3									7	
Surgo.....		4											
Ocean whitefish.....	3												
Pink seaperch.....	16					1		6			8+	7	8+
Buttermouth seaperch.....				1								1	
Sharptnose seaperch.....	3							1	1			1	1
Rubberlip seaperch.....	3											2	
Pile perch.....	1	3						1				4	
Blacksmith.....	1,032	1,978	334	289	39			47		4	2	2,687	6
Caribaldi.....	1												
California sheepsteud.....	3+	63	3	1	2			1				70	
Opaleye.....	3												
Bocaccio.....	4			12							1	12	1
Bass rockfish.....	30		2	13				1				16	

Vermilion rockfish.....	15+	--	--	--	--	--	--	--	5*	2	5*
Kelp rockfish.....	25	1	4	7	--	--	--	2	--	16	--
Widow rockfish.....	1	--	--	--	1	--	--	--	--	1	--
Spotted rockfish.....	83	--	3	1	--	--	--	192	--	197	1
Halfband rockfish.....	9	--	--	--	--	--	--	3	--	5	--
Speckled rockfish.....	46	--	--	--	1	--	--	2	4*	3	4*
Rosy rockfish.....	7	--	--	--	--	2	1	--	--	3	--
Greenspotted rockfish.....	7	--	--	--	--	3	--	3	1*	6	1*
Pink rockfish.....	10	--	--	--	15	6	6	2	1*	23	1*
Starry rockfish.....	3	--	--	--	3	2	2	1	2*	6	2*
Spanishflag.....	--	--	--	--	--	--	--	1	--	1	--
Striped rockfish.....	1	--	--	--	--	--	--	--	1*	--	1*
Brown rockfish.....	--	--	1	--	--	--	--	--	--	1	--
Whitebelly rockfish.....	2	--	--	--	--	--	1	--	--	--	1
Calico rockfish.....	1	--	--	--	--	--	--	--	--	--	--
Troutfish.....	1	--	--	--	--	--	--	--	--	--	--
Rockfish (species?, very yg.)	--	--	--	--	--	--	--	--	--	--	--
Crested goby.....	--	--	--	--	--	2	2	--	--	2	--
Zebra goby.....	1	--	1	7	--	--	--	--	--	8	--
Northern midshipman.....	2	--	--	--	--	--	--	--	--	--	--
Spotted cusk-eel.....	7	--	--	--	--	2	--	1	--	1	--
Totals.....	1,431 +	2,134	359	369	80	117	12	286	99 +	3,357	121 +

* Fish so marked, plus 50 to 100 additional pink seaperch that were not recovered, were presumably destroyed by the unscheduled blast northwest of the main explosions.

The local fish population presumably recovered between the operations of April 6-7 and May 23-24. The similarity between the lists of fishes destroyed on the two occasions (Table 1) is striking.

During the second operation, on May 23 and 24, an effort was made to tally all fish killed. Six 50- or 100-pound charges were set off, four on May 23 and two, close together, on May 24, near the sandy heads of South Branch and Sumner Branch, in depths of 50 to 90 feet; and six were discharged in the rocky main canyon, at depths of about 325 to 450 feet, four on May 23 and two on May 24; in addition, one unscheduled 4-pound charge was exploded on May 24, above the northwestern wall of the main canyon. The two sets of explosions were discharged to either side of the area blasted on April 6 and 7. In view of the large radius of kill observed, however, it is assumed that the canyon was affected not only near each set of shots but also through much of the intervening area. Due to the extreme narrowness and straight alignment of the rock-walled canyon, it may be assumed that the effects of the explosions were intensified up and down the trench.

The very extensive kill on the first day (May 23) was probably almost complete for the regions affected. Approximately duplicated shots of the second day yielded only 121 fish. Of these, 89, or 74 percent, were silversides (*Atherinidae*), free-swimming fish whose numbers were presumably unaffected by the explosions of the previous day. Of the 32 remaining fish, 22 (marked with an asterisk in Table 1) were almost certainly killed above the northwestern canyon wall or on the canyon edge, for they appeared well north of the others and later, presumably as the result of the unscheduled 4-pound shot set off in that region near the surface. Eliminating these two sets of specimens, only 10 fish were taken as a result of the four shots of the second day, where 3,357 were picked up following the eight shots on the first day. It seems possible that most of the fish population was destroyed through perhaps 1,000 or 1,500 feet of the upper part of the submarine canyon. The destructiveness of large dynamite charges may be very extensive.

In the four successive shallow-water shots of May 23 there was a marked decrease in the kill, particularly in the series (1, 2, and 4) at the head of Sumner Branch (Table 1 and Figure 1). Had the fish merely moved down into the main Scripps Canyon, more would likely have been killed by the subsequent charges (6-8) in deeper water. The rather high mortality from blast 8, contrasting with the lesser kill of blast 5, discharged about two hours earlier at the same location, may have resulted from a down-canyon movement of the fish between the two shots.

It is obvious that the bottom fish did not move into the canyon overnight, between the days in May when the explosions were set off, either from possible refuges in the steep-walled tributaries or from more distant habitats. There is reason to believe, however, that the population was again restored within a few months. In extensive diving operations with self-contained units Conrad Limbaugh and other students found during 1951 that fish again abounded in the canyon, in the general region where the fish life had been largely eliminated on May 23-24, 1950. Here at depths of 35 to 185 feet Limbaugh observed 31 species of fish (for scientific names see list p. 366). The blacksmith, again the most abundant fish, was observed in particularly large concentrations at the heads of canyons and at the junctions of the tributaries. Various species of rockfish were seen

in considerable numbers along the rim of the canyon below 100 feet and at the canyon junctions. At depths of 50 to 100 feet, along the rim, kelp bass and ocean-whitefish were observed at times in large schools. Several seaperches (*Embiotocinae*) were occasionally found in large numbers at depths of 35 to 60 feet. At times large schools of señoritas were seen at depths less than 50 feet. In general, in 1951, fish were apparently more numerous in and over the canyon than in any comparable near-by area. The fish life of the canyon, which is often favored by local anglers, had seemingly become restored.

1951 EXPERIMENTS

In 1951 experiments were conducted for the specific purpose of determining whether methods applicable to seismographic exploration for oil might be found that would cause no considerable fish mortality. These trials were conducted by the Union Oil Company of California on the exploring ship *Subnarex*, under a permit granted by the California Department (then Division) of Fish and Game on March 2, 1951 (later amended). The operations were restricted in several ways and the permit specified that the experiments would be a joint enterprise of the oil company and the Scripps Institution of Oceanography of the University of California. A preliminary report was prepared in May, 1951, for the use of the State Fish and Game Commission and of other parties particularly concerned. It serves as the main basis for this presentation.

At the outset of these experiments the object was to determine whether small charges of dynamite jetted into the bottom (Figure 2) might be exploded without causing serious harm to the fish life in the overlying water. It was determined, however, that fish confined in experimental cages and others, free-swimming, were seriously affected. After repeated trials failed to indicate that small jetted charges of either dynamite or Hereomite would be innocuous, experiments were undertaken with explosives (Hercules FFG and FFFG black powders) having lower peak intensities and lower frequencies.

The black powder charges were first jetted into the bottom, but when it appeared that the bubble pulse produced by such powder when jetted as deep as 40 feet might interfere with the geophysical analysis, the project was expanded (by extension of the permit) to include trials with the charge lying on the bottom and with the charge hung a few feet below the surface.

The experiments were observed by Edward Greenhood, representing the Department of Fish and Game, as well as by the Scripps representative (Rechnitzer) and the Union Oil Company's geologist (William W. Rand). On several occasions other officials of the Scripps Institution and of the California State Fisheries Laboratory observed the trials and on one day Messrs. DeWitt, Harrison, and Woods, representing the Ocean Fish Protective Association, were aboard. The stipulations of the permit (as amended) were rigidly adhered to and every facility was provided for the conduct of the experiments and for the observation and recording of the results. A boat with crew (Figure 4) was made available to the observers. The boat stood by in readiness for each shot, in order to pick up any marine life that might be killed or injured by the blast. All information regarding the methods involved in carrying out the experiments



and all information gathered from them were made available to the observers.

The work was started off Silver Strand, which separates San Diego Bay from the ocean. Explosions 6, 9-13, and 16, as seriated in Tables 2-4, were set off here. The next test (25) was made just north of La Jolla. The work was then transferred to the vicinity of the Orange-Los Angeles county line, after sedimentary overburden of adequate depth for the jetted tests could not be located off San Diego County.

In each set of experiments an effort was made to keep as nearly uniform as possible all varying factors other than size and position of the charge.

Materials and Methods

Fishes

Seven species of fish, marked by an asterisk in the list on page 366 were used in the experimental cages. Some individuals of each kind were killed in cages by the dynamite charges. Four of these species and seven others were killed by dynamite while free-swimming. These are marked by a dagger (†). In the two Herecomite trials anchovies and one queenfish were killed. In the black powder experiments only the anchovy was killed in cages and one Pacific mackerel was the only fish killed while free-swimming.

The number of species used in the experiments was limited because few kinds were readily available. Anchovies were frequently the only kind obtainable; jack mackerel, kingfish, sardine, queenfish, pompano, and grunion made up a very small percentage of any single purchase. In the San Diego area fish were taken when available, either from holding receivers or directly from the fishing boat. In the San Pedro area fish were purchased daily from local bait dealers at approximately 7.30 a.m., within eight hours after capture. The specimens were taken directly from their holding tanks. Therefore, the fish, after transfer to the holding tank on the research vessel, had been handled only twice by dipnets and were taken from the ocean as recently as was practicable. None were held over from the operations of the previous day. The kingfish were mostly taken by hook and line. They were seemingly sound when placed in the cages. In general, the fish were in excellent condition and were considered to be suitable experimental material.

The fish were held in a 4' × 4' × 4' wooden commercial-type bait tank, through which at all times an adequate flow of fresh sea water was maintained by an air-free pump. The tank was placed on board where the fish when dip-netted out of the tank could be transferred rapidly in a bucket to the live cages (Figure 5). All fish kept well throughout the experiments. Fatalities due to handling were negligible. It was found by experiment that internal injuries, such as those produced by a blast, could be simulated only by extraordinarily rough treatment.



FIGURE 2. Jetting a charge into the ocean floor. Photograph by William W. Rand, April, 1951.

FIGURE 3. Loading position of the nine-cage unit. Photograph by William W. Rand, April, 1951.

FIGURE 4. Motor launch scouting for possible free kill. Photograph by William W. Rand, April, 1951.

FIGURE 5. Loading fish into a bottom cage. Photograph by William W. Rand, April, 1951.

Cages

In order to avoid possible absorption of shock-wave energy by such air-containing material as twine netting and wooden frames, all cages were constructed of $\frac{1}{2}$ -inch mesh galvanized hardware cloth laid over a welded frame of $\frac{1}{2}$ -inch steel rod (Figure 6). They were similar to those used in previous investigations (Aplin, 1947; Anonymous, 1948). The dimensions of each were 18" \times 36" \times 36". A door 18" \times 18" was placed on one 18" \times 36" side. Usually only two cages were used in each experiment, one near the surface and one on the bottom. In some experiments, nine cages were secured five feet apart, both vertically and horizontally, by an angle-iron frame (Figure 7). The nine-cage unit was held in an upright position by four buoys. To this unit an extra buoyed surface cage was attached.

Control cages, one at the surface and one on the bottom, were placed in a few experiments 100 to 200 feet from the shot. None of the fish in the controls showed any damage attributable to the blast.



FIGURE 6. All-metal holding cage (18" \times 36" \times 36"). Photograph by William W. Rand, April, 1951.

Handling of Cages

The cages were submerged on edge to a depth of 18 or more inches alongside a launch that was tied to the research vessel (Figure 5). The launch permitted the operating crew to work at water level. The fish were gently poured from the bucket into the live cage. When the door was secured the cage was completely submerged. Once in the water, the cage righted itself, due to the bridling, so that the fish were limited in vertical movement to 18 inches. The cages were then placed in position for the firing of the charge. Loading time for each cage was about one minute.

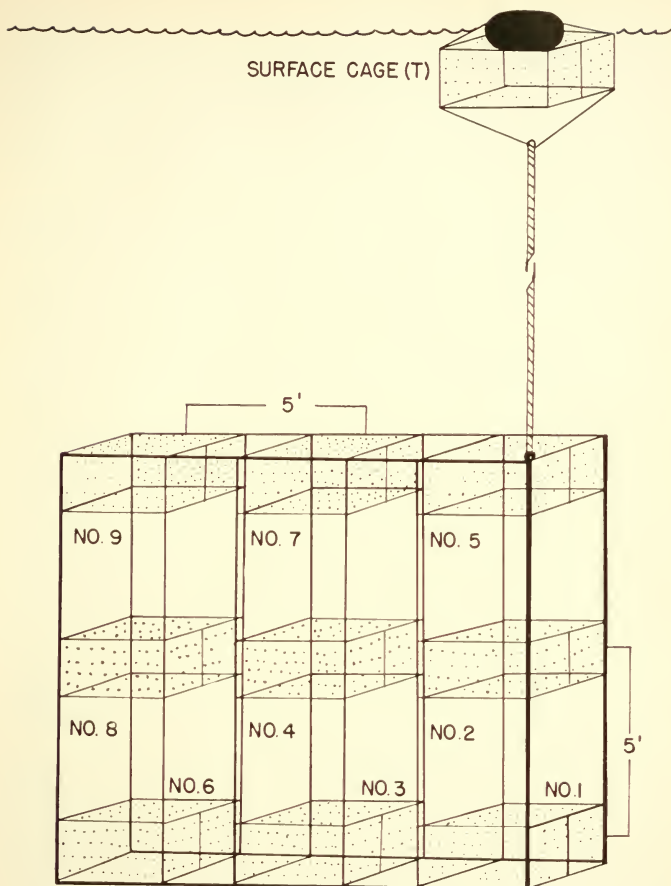


FIGURE 7. Nine-cage unit. No. 1 cage oriented nearest to jet hole.

The nine-cage unit, suspended from a boom, was loaded as it was held at 90 degrees from its final position, so that the door of each cage was up (Figure 3). When a row of three cages had been loaded, as described above, the unit was lowered so that the next row could be similarly filled. On completion of the loading, which required about 15 minutes, the cage was turned to its original position with a 36" \times 36" side up.

A recording instrument was attached to the top of one of the cages, which was placed as nearly vertically over the shot as was feasible. The specific cage from the bottom is indicated in Tables 2-4. The recording

device measured the peak intensity of the shock wave (Figures 8-9, which is recorded in p.s.i. (pounds per square inch). It is assumed, in general, that the fish in a particular cage were subjected, approximately, to the pressure indicated by the instrument attached to that cage, but in some experiments (as in Exp. 19), the fish were probably subject to less pressure because they were in the shadow zone (p. 362). It would have been better to have placed the instrument in the center of the cage, as was done in the Chesapeake Bay experiments (Anonymous, 1947, 1948).

When the charges were jettied, a crew member standing on the research vessel placed the nearest bottom cage (No. 1) as close to the jet hole as he could. He set the cages free when they were aligned with the shot wire leading to the jettied charge. Precise placement of the No. 1 cage proved difficult, particularly in deep water. The actual distance between charge and cage ("Hydrophone Dist." in Tables 2-4) was computed whenever the hydrophone was attached to a cage. The lower cage normally rested on the bottom and was equipped with a grapple to restrict its movement during the experiment. The paired cages were secured together by a line. The upper cage, supported by a steel buoy, floated just beneath the surface.

In those experiments (1, 40-44, 46, 50; Tables 2, 4), in which the explosive was floated either two or four feet beneath the surface, the upper cage floated just beneath the surface, but was held off to the side of the explosion rather than approximately over the blast. This was accomplished by a line 20 feet long, which was kept taut by another line running to the research vessel. The lower cage was suspended in mid-water either 40 feet below the charge or 40 feet below the surface cage.

In four experiments (51, 52, 60, 61) the bottom cage was separated either 5 or 10 feet from the charge by a metal rod and the recording instrument was attached to this cage.

Within about 10 or 15 minutes, after all the equipment was set in place, the ship was moved approximately 100 feet from the site of the blast. Immediately after the firing the launch was run to the site of the shot, in order to make prompt observations of caged fish and of whatever free marine life might surface.

As soon as it was evident that no free-swimming fish were damaged or that all that were going to surface had already done so, the cages were pulled aboard the launch and the fish were removed for dissection, analysis, and preservation. Controls indicated that it was unnecessary to leave fish in cages for any prolonged period, as dissection reveals the damage. It is believed that the damage is produced almost momentarily by the blast. All fish subjected to experiments involving black powder were dissected immediately on board the research vessel and were then preserved.

Handling of Charges

A standard factory-prepared charge of five pounds of 60 percent strength dynamite was used. Smaller charges were prepared from sections of a five-pound stick. Larger charges were formed by binding five-pound units together.

Initially a quantity of Hercules FFG or FFFG powder was weighed out on a spring balance and placed in a piece of automobile radiator hose. Subsequent charges of approximately the same weight were prepared by filling sections of hose of equal length with powder. Charges exceeding 20 pounds, with the exception of the 40-pound charge in Experiment 45, were packed in two types of containers, which gave different results. The 45-pound charges were placed either in five-gallon shark-liver cans (each holding approximately 45 pounds, as determined by R. A. Peterson, of United Geophysical Company), or in two sheet-metal tubes, which were bound together to make a charge of about 40 pounds. Each tube was approximately five inches in diameter and twenty-five inches long. One detonator was placed in each tube and one in each five-gallon tin. The charge sizes as recorded in the table were obtained from William W. Rand.

Pressure Measurements

The pressures, recorded in pounds per square inch (Tables 2-4), were calculated by and obtained from E. Pat Shultz and Robert Day of the United Geophysical Company. The measurements were made with an underwater piezoelectric (tourmaline) gauge of type B (as illustrated by Cole, 1948, Fig. 5.11). Shultz reports (in letter) that "much of our technique followed the methods of Cole, and we used the well-known "Q-Step" system of calibration described by him on page 192, together with gauge constants supplied by the makers (Cambridge Thermionic Corp.) and independently checked by us with measurements of explosives (TNT) of standardized strength."

Permanent records were obtained by photographing the screen of a cathode-ray oscilloscope. Sample records for dynamite and black powder explosions illustrate a fundamental difference (Figures 8-9). The dynamite explosion record shows the sharp, violent nature and abrupt front of the pressure peak, as contrasted with the slow development of peak pressure of small amplitude from a black powder explosion.

During these trials it was found by Shultz that, when plotted on a log-log scale, the peak pressure near the bottom from jetted five-pound dynamite charges bore a linear relationship (Figure 10) to the distance from the explosion (the "Hydrophone Dist.") and the pressure decreased inversely as the 2.6 power of the distance, rather than the approximately 1.15 power usually reported for sea water.

Miscellaneous Data

Locality of each operation was obtained from the captain of the research vessel. Water depths were read directly from a Bludworth fathometer which signals in both fathoms and feet. Bottom samples were obtained from the jetting apparatus; in some experiments, also by diving. Rechnittzer and Limbaugh occasionally dove with self-contained diving apparatus in an attempt to determine effects that were not visible at the surface.

Criteria for Damage

To stay on the safe side from the standpoint of the conservation and utilization of the fishery resources, rigid criteria were adopted for estimating the damage done to fish. Any apparent injury not definitely

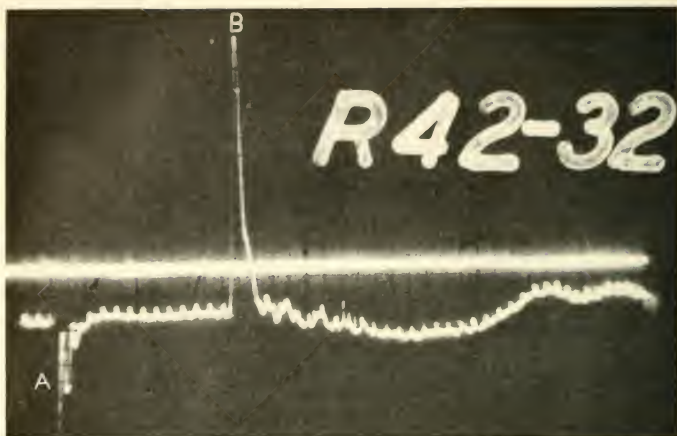


FIGURE 8. Oscillogram of 5-lb. dynamite explosion No. 19. (A) Charge fired. (B) Peak pressure, 83 p.s.i. The distance from (A) to the base of peak (B) measures the time required for the shock to travel from the explosion to the hydrophone. The distances between the small peaks represent milliseconds. Photograph by E. Pat Shultz and Robert Day, April, 1951.



FIGURE 9. Oscillogram of 5-lb. black-powder explosion No. 65. Peak pressure (B), 6.8 p.s.i. Photograph by E. Pat Shultz and Robert Day, April, 1951.

attributable to handling or to other causes than that of the explosion was interpreted as an indication of probable death due to the blast. It is thought highly probable that most fish seriously injured by a blast would succumb later, through weakness, disease, or predation. Under favorable conditions, however, some and perhaps many of the affected fish, particularly those that are only temporarily stunned, probably recover and survive without permanent harm. The criteria, therefore, may have been too rigid. Further research is indicated.

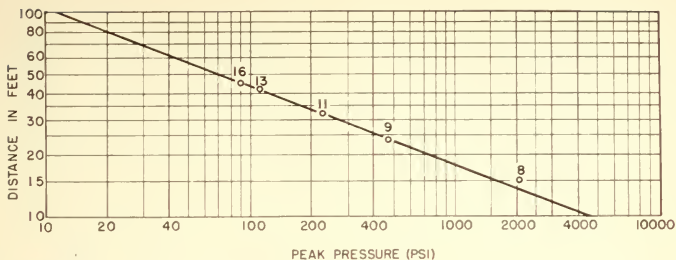


FIGURE 10. The decay with distance of the pressure from 5-lb. dynamite charges (decreasing inversely as the 2.6 power of the distance). Redrawn from graph prepared by E. Pat Shultz.

Internal damage, as determined by dissection, involved: (1) any hemorrhaging obviously not due to dissection, regardless of whether or not the cause of the bleeding was determined; (2) any break in the viscera or peritoneum; (3) a burst air-bladder; (4) a ruptured kidney; (5) gonad damage, or milt or eggs free in the abdominal cavity. Usually but not always any one of these symptoms was accompanied by several others, but in some tests only one was apparent.

Controls indicated that hemorrhaging in the muzzle and eyes of anchovies was due to confinement in the cages.

Results

Sharply contrasting results were obtained with dynamite (Table 2) and black powder (Table 4). Some comparative data were secured with Hercomite (Table 3).

The largest dynamite charges used in these experiments (10 pounds) do not compare with those that were often employed in the earlier seismographic studies nor with those utilized in the submarine-canyon studies reported above. Fish kills, nevertheless, resulted.

Ten-pound Charges of 60 Percent Dynamite

Whether exploded just below the surface (Exp. 1) or jetted 50 to 55 feet into the bottom sediment (Exps. 2-3), the 10-pound charges proved fatal to fish. The surface explosion, as would be expected from previous operations, killed fish (8 sauries). It was set off without the use of caged fish, to determine whether fish were present where they were not being killed by black powder. Both jetted blasts killed caged fish. One explosion destroyed caged fish from surface to bottom. The other blast, with somewhat lower indicated peak intensity, killed fish in the surface cage but not in the bottom container; in addition it destroyed two free-swimming fish.

Five-pound Jetted Dynamite Charges

The 19 experiments (Nos. 4-22) performed with a five-pound jetted charge of 60 percent dynamite also indicated fatal results. This charge was used most frequently for three reasons: (1) it was thought to be desirable from a seismographic viewpoint; (2) this size of charge was most conveniently handled in the jetting operation; and (3) it was desired to have an experimental standard.

TABLE 2
Data on Effects of Underwater Explosions With 60 Percent Dynamite

The experiments are here numbered in sequence from more lethal to less lethal results, without reference to the sequence in which the trials were run. Controls are marked "Contr." in place of the pounds of the charge. Under "Location," "down" means below surface, "Bott." indicates that the charge lay on the bottom, and "J." stands for jettied. Under "Hydrophone Loc." (location), "Surf." and "Bott." respectively indicate attachment to surface cage or to bottom cage. The "Nos." in this column and under "Cage Loc." (location) refer to the cage numbers in the multiple-cage trials (Figure 7). "Hydrophone Dist." (distance) from charge was computed from the seismographic record. Full vernacular names and the scientific names are given on p. 366. Under "Free Fish Killed" the total kill of unaged fish is estimated, including fish seen to be eaten by gulls and those seen swimming with greatly disturbed equilibrium.

Exp.	Lbs.	Location	Hydrophone		Peak p.s.i.	Water depth, feet	Cage loc.	Fish species	Fish in cages		Free fish killed
			Loc.	Dist., feet					Unharmed	Killed	
1	10	4' down	---	---	---	100	None	Saury			8
2	10	J. 50'	Surf.	82	82	29	Surf.	Sardine	0	1	0
								Anchovy	0	8	0
								Jack mackerel	0	2	0
								Pompano	0	1	0
								Sardine	2	0	0
								Anchovy	6	0	0
								Jack mackerel	2	0	0
3	10	J. 55'	No. 5	52	148	30	Surf.	Kingfish			2
								Anchovy	0	18	0
								Anchovy	7	0	0
								Anchovy	0	10	0
								Anchovy	10	1	0
								Anchovy	8	5	0
								Anchovy	0	16	0
								Anchovy	0	7	0
								Anchovy	7	13	0
								Anchovy	0	16	0
3	Contr.						Surf. Bott.	Anchovy	0	6	0
								Anchovy	10	0	0
								Anchovy	11	0	0

4	5	J. 5'	--	--	27	None	Queenfish Kingfish	--	4
5	5	J. 7'	Bott.	61	163	None	Jacksnelt White seaperch	--	3
6	5	J. 15'	Bott.	--	403	Surf. Bott.	Anchovy Anchovy Jacksnelt	0 0 3	0 0 200
7	5	J. 15'	Surf.	49	176	Surf. Bott.	Anchovy Anchovy Jacksnelt	0 0 12	0 0 20
8	5	J. 15-18'	No. 2	22	1,343	Surf. Nos. 1-9	Anchovy Anchovy Jacksnelt White seaperch	0 0 51 --	0 0 80 1
8	Contr.					Surf. Bott.	White seaperch White seaperch	14 6	0 0
9	5	J. 25'	Bott.	24	468	Surf. Bott.	Anchovy Anchovy Jacksnelt Grunion	0 0 2 --	0 0 200 2
10	5	J. 30'	Bott.	29	501	Surf. Bott.	Anchovy Anchovy	4 ¹ 4 ¹	0 0
11	5	J. 32'	Bott.	32	225	Surf. Bott.	Anchovy Anchovy Pacific mackerel Kingfish	0 0 3 --	0 0 1 4
12	5	J. 35'	Bott.	43	89	Surf. Bott.	Anchovy Anchovy	0 6	0 0
12	Contr.					Surf.	Anchovy	11	0

¹ These fish, in five of the earlier experiments, were not dissected and might have had internal injuries, which later would have been regarded as indicative of probable death.

TABLE 2—Continued
Data on Effects of Underwater Explosions With 60 Percent Dynamite

Exp.	Lbs.	Location	Hydrophone		Peak p.s.i.	Water depth, feet	Cage loc.	Fish species	Fish in water		Free fish killed
			Loc.	Dist., feet					Unharmed	Killed	
13	5	J. 35-40'	Bott.	42	111	56	Surf.	Queenfish Kingfish Kingfish	10 10 20	0 0 0	0 0 0
14	5	J. 40'	Bott.	50	110	78	Surf.	Anchovy Jack mackerel Kingfish Anchovy Jack mackerel Kingfish	10 3 3 6 2 3	0 0 0 0 0 0	0 0 0 0 0 0
15	5	J. 40'	No. 5	44	106	30	Surf. Nos. 1-9	Anchovy Anchovy	10 37	0 0	0 0
15	Contr.						Surf. Bott.	Anchovy Anchovy	3 7	0 0	0 0
16	5	J. 40'	Bott.	45	90	82	Surf. Bott.	Anchovy Anchovy	6 1	0 0	0 0
17	5	J. 40'	Surf.	--	43	26	Surf. Bott.	Anchovy Jack mackerel Kingfish Anchovy Kingfish Shiner scapereh	3 1 0 7 0 0	3 2 2 0 1 1	0 0 1 0 0 1
17	Contr.						Surf.	Sardine Anchovy Jack mackerel Anchovy Jack mackerel	2 4 1 5 3	0 0 0 0 0	0 0 0 0 0
18	5	J. 45'	--	--	--	30	Surf. Bott.	Anchovy Anchovy Kingfish	0 0 0	10 6 1	0 0 1

19	5	J. 45'	Bott.	65	83	92	Surf. Bott.	Anchovy Anchovy	4 6	2 0	0 0
20	5	J. 50'	Bott.	--	106	30	Surf.	Sardine Anchovy Jack mackerel	2 ¹ 3 ¹ 4 ¹	0 0 0	0 0 0
							Bott.	Sardine Anchovy Jack mackerel	3 ¹ 1 ¹ 1 ¹	0 0 0	0 0 0
20	Contr.						Surf.	Sardine Anchovy Jack mackerel	2 4 1	0 0 0	0 0 0
							Bott.	Anchovy Jack mackerel	5 3	0 0	0 0
21	5	J. 50'	No. 5	67	76	30	Nos. 1 9 1 2, 4 9	Anchovy Jack mackerel	83 11	0 0	0 0
22	5	J. 65'	No. 5	--	--	30	Surf. Bott.	Anchovy Anchovy	0 0	9 5	0 0
23	2½	J. 15'	Surf.	59	125	30	Surf. Bott.	Anchovy Anchovy	0 5	7 2	0 0
24	2½	J. 15'	Surf.	75	50	30	Surf. Bott.	Anchovy Anchovy	4 7	0 3	0 0
25	2½	J. 35-40'	Bott.	--	162	56	Surf. Bott.	Anchovy Anchovy Jack mackerel Pacific mackerel Slim midshipman Pipfish	0 7 -- -- -- --	8 2 -- -- -- --	0 0 310 1 1 1
26	1¼	J. 10'	Surf.	34	186	28	Surf. Bott.	Anchovy Anchovy Jacksmelt	0 0 --	6 7 --	0 0 5
27	1¼	J. 10'	--	--	--	30	None	Jacksmelt White seajeroh	-- --	-- --	1 1

¹ These fish, in five of the earlier experiments, were not dissected and might have had internal injuries, which later would have been regarded as indicative of probable death.

TABLE 2—Continued
Data on Effects of Underwater Explosions With 60 Percent Dynamite

Exp.	Lbs.	Location	Hydrophone		Peak p.s.i.	Water depth, feet	Cage loc.	Fish species	Fish in cages		Free fish killed
			Loc.	Dist., feet					Unharmed	Killed	
28	1¼	J. 15'	No. 5	20	296	30	Nos. 1-3, 5-9 No. 4	Anchovy Anchovy Grunion	7 0 0	38 6 1	0 0 0
29	1¼	J. 15'	Surf.	43	117	30	Surf.	Anchovy Grunion	0 0	5 2	0 0
30	1¼	J. 15'	Bott.	52	30	30	None	Anchovy	—	—	0
31	1¼	J. 15'	Bott.	54	24	30	Surf.	Anchovy	6	0	0
32	1¼	J. 25'	Surf.	60	73	29	Surf.	Anchovy Grunion	0 0	4 2	0 0
33	1¼	J. 30'	Bott.	26	128	29	Bott.	Anchovy	0	5	0
34	1¼	J. 30'	Surf.	65	54	29	Surf.	Anchovy Grunion Anchovy	2 0 3	7 1 4	0 0 0
35	1¼	J. 30'	Surf.	68	50	29	Bott.	Anchovy Grunion Anchovy	6 2 8	0 0 0	0 0 0
36	1¼	J. 30'	Surf.	65	45	29	Surf.	Anchovy Grunion Anchovy	4 0 5	2 2 0	0 0 0
							Bott.	Anchovy Grunion Anchovy	6 1 10	0 0 0	0 0 0

TABLE 3
Data on Effects of Underwater Explosions With Hercomite
For abbreviations see sublegend to Table 2

Exp.	Obs.	Location	Hydrophone		Peak p.s.f.	Water depth feet	Charge type	Fish species	Fish in cages		Free fish killed
			Loc.	Dist., feet					Unharmed	Killed	
37	4	J. 20'	Bot.	17	163	30	Surf. Bot.	Anchovy Anchovy Queenfish	0 0 0	9 5 1	0 0 0
38	4	J. 30'	Bot.	29	138	30	Surf. Bot.	Anchovy Anchovy	0 0	12 9	0 0
38	Contr.						Surf. Bot.	Anchovy Anchovy	4 1	0 0	0 0
39	Contr.					30	Surf. Bot.	Anchovy Anchovy	5 5	0 0	0 0

TABLE 4
Data on Effects of Underwater Explosions With FFG and FFG Black Powder
For abbreviations see sublegend to Table 2

Exp.	Lbs.	Location	Hydrophone		Peak p.s.i.	Water depth, feet	Cage loc.	Fish specimen	Cylindrical		True fish count
			Loc.	Dist., feet					Uninjured	Killed	
40	45	4' down	Bott.	43	160	100	Surf. Bott.	Anchoy	0	0	0
								Anchoy	0	0	0
								Pompano	0	0	0
41	45	4' down	Bott.	39	124	100	Surf.	Pacific mackerel	0	0	0
								Anchoy	0	0	0
42	45	4' down	Bott.	23	—	100	Surf.	Anchoy	0	0	0
43	40	1' down	Bott.	61	—	100	Surf.	Anchoy	0	0	0
								Anchoy	0	0	0
44	40	4' down	Bott.	56	—	100	Surf.	Anchoy	0	0	0
								Anchoy	0	0	0
45	40	J. 10'	Bott.	37	41	30	Surf.	Anchoy	0	0	0
46	20	4' down	Surf.	21	20	100	Surf.	Anchoy	0	0	0
47	20	J. 10'	—	—	—	—	None	Anchoy	0	0	0
								Anchoy	0	0	0
								Anchoy	0	0	0
48	20	J. 10'	Bott.	17	48	30	Surf.	Queenfish	0	0	0
								Anchoy	0	0	0
49	20	J. 10'	Bott.	14	58	30	Surf.	Anchoy	0	0	0
								Anchoy	0	0	0
50	10	2' down	Bott.	23	—	100	Surf.	Anchoy	0	0	0
								Anchoy	0	0	0
51	10	Bott.	Bott.	14	—	30	Surf.	Grunion	0	0	0
								Anchoy	0	0	0
52	10	Bott.	Bott.	21	—	30	Surf.	Anchoy	2	4	0
								Anchoy	0	0	0
53	10	J. 5'	—	—	—	30	Surf.	Anchoy	0	0	0
								Anchoy	0	0	0
54	10	J. 5'	—	—	—	30	Surf.	Anchoy	0	0	0
								Anchoy	0	0	0
55	10	J. 10'	Bott.	20	10.8	30	Surf.	Anchoy	0	0	0
								Jack mackerel	0	0	0
								Anchoy	0	0	0

56	10	J. 10'	Bott.	12	4.0	30	Surf.	Anchovy	4	0	0
							Bott.	Kingfish	2	0	0
								Anchovy	5	0	0
57	9	J. 20'	Bott.	75	4.0	92	Surf.	Jack mackerel	2	0	0
								Kingfish	2	0	0
58	9	J. 20'	Bott.	27	11	92	Bott.	Anchovy	8	0	0
59	9	J. 20'		—		92	Surf.	Anchovy	5	0	0
							Bott.	Anchovy	3	0	0
60	5	Bott.	Bott.	11	38	30	Surf.	Anchovy	8	0	0
61	5	Bott.	Bott.	10	32	30	Bott.	Anchovy	4	0	0
62	5	J. 5'	Bott.	13	6.7	30	Surf.	Anchovy	6	0	0
								Anchovy	9	0	0
								Anchovy	9	0	0
								Anchovy	11	0	0
								Grunion	1	0	0
								Kingfish	1	0	0
							Bott.	Anchovy	11	0	0
								Grunion	1	0	0
								Anchovy	2	0	0
63	5	J. 5'	Bott.	92	1.7	30	Surf.	Kingfish	10	0	0
								Anchovy	1	0	0
								Pompano	1	0	0
								Kingfish	1	0	0
							Bott.	Anchovy	7	0	0
								Anchovy	1	0	0
64	5	J. 10'	Surf.	38	4.5	30	Surf.	Kingfish	7	0	0
								Anchovy	7	0	0
								Pompano	1	0	0
								Jack mackerel	1	0	0
							Bott.	Anchovy	7	0	0
								Pompano	1	0	0
65	5	J. 10'	Bott.	19	6.8	30	Surf.	Jack mackerel	1	0	0
								Anchovy	4	0	0
								Pompano	4	0	0
								Jack mackerel	1	0	0
							Bott.	Anchovy	6	0	0
								Jack mackerel	3	0	0
								Queenfish	1	0	0
66	5	J. 10'		—	—	30	Surf.	Anchovy	4	0	0
								Queenfish	2	0	0
								Anchovy	1	0	0
67	4	J. 20'	Bott.	25	7.8	92	Bott.	Anchovy	8	0	0
							Surf.	Anchovy	4	0	0

Some of the variation in the indicated kill is attributable to the fact that the test fish in some of the early trials, listed in Table 2 as Exps. 10, 13, 15, 16, and 20, were not dissected immediately and hence might have shown, on closer scrutiny, signs of injury (p. 347) that we construe as probably fatal. The peak intensity of shock recorded for these experiments is well above the apparent lethal threshold of 40 to 70 p.s.i. indicated by other experiments (as Exp. 17), and measured as indicated on p. 345.

Five-pound charges damaged fish at distances of about 65 feet (measured by hydrophone data in Exp. 19 and estimated from the jetted depth in Exp. 22). A pressure of 83 p.s.i., however, was recorded in Exp. 19 at the bottom cage where fish were apparently unharmed. It is probable that the fish were in the shadow zone (p. 362) of the focused compression wave.

The dampening effect of the bottom sediments on the shock wave was usually not great enough to eliminate the lethal effects of five-pound dynamite explosions, even though most of the trials were run where there is a very deep sedimentary overburden of clay-sand mixture, which is thought to be more effective than sand in decreasing the transmitted energy. The hard-rock surface here is presumably too deep to produce an effective reflection of the downward component.

With increase in depth of jetting there was, with some irregularities, a decrease in the observed kill. Large kills of free-swimming fish were recorded only for shots jetted less than 30 feet. At intermediate depths of jetting the kill was commonly greater in the surface than in the bottom cage. When the five-pound charge was jetted deeper than 35 feet (10 experiments, Nos. 13-22), there was usually little or no kill in either surface or bottom cage, or in the surrounding water. In two trials (No. 18, charge jetted to 45 feet, and No. 33, charge jetted to the greatest depth attained in any of the experiments, 65 feet), however, there was complete destruction of the fish in both cages. Clearly, the effects of dynamite explosions are difficult to interpret and unsafe to predict.

Two and One-half Pound Jetted Dynamite Charges

Caged fish were damaged in all three experiments (23-25) using 2½ pounds of 60 percent dynamite. Experiment 25 resulted in the killing of more free fish than any other during the entire test period. Forty-four jack mackerel, one Pacific mackerel, one midshipman, and one kelp pipefish were recovered. Approximately 300 additional jack mackerel were injured but did not surface completely. They were sufficiently incapacitated to make us believe that they probably would not have recovered before being preyed upon by predators, such as sea lions, several of which, in fact, soon entered the experimental area and probably fed on the injured fish. By diving, an attempt was made to estimate the total number of fish killed or damaged, but turbidity rendered the observations incomplete. Although it was estimated that the charge was jetted 35-40 feet into the sand bottom, the recorded peak pressure of 162 p.s.i. at the surface and the heavy kill suggest that the charge may have been inadvertently pulled to a shallower depth, or that the location of the charge very close to the underlying hard rock may have nearly doubled the intensity of the shock in the water. In the two other experiments no free-swimming fish were killed and the destruction of caged fish was about two-thirds and one-fifth, respectively.

One and One-quarter Pound Jetted Dynamite Charges

The lethal effects on fish of underwater explosions of jetted dynamite were by no means eliminated by a reduction of the charge to only 1½ pounds. Free-swimming fish were killed by the two explosions at the jetted depth of 10 feet (Exps. 26-27), but none were destroyed in the nine trials (Exps. 28-36) in which the charge was jetted 15 to 30 feet. Of the nine experiments in which cages were used, there was a partial to complete kill of the caged fish in six trials. In Exp. 26, with the charge jetted to 10 feet, all 13 of the caged fish plus 5 free-swimming jacksnelt were killed. In Exp. 28, with the charge jetted to 15 feet, 45 out of 52 experimental fish were destroyed. In another trial (Exp. 29), with the same depth of jetting, all fish were killed; in yet another (Exp. 31), all survived. In Exp. 32, with the charge at 25 feet, there was a complete kill. In the three runs with the explosion at 30 feet the results were varied. In the whole series there was a heavy to complete kill when the peak p.s.i. was recorded as greater than 70, and little or no kill when the peak was below 60 pounds.

Four-pound Jetted Hercomite Charges

When it became apparent that even very small jetted charges of dynamite often kill fish, two trials were run with Hercomite powder (Table 3), in water 30 feet deep. Four-pound charges were jetted 20 and 30 feet, respectively. Peak pressures of 193 and 138 p.s.i. were recorded at the bottom cages, respectively 17 and 29 feet from the blast (measured instrumentally). These determinations indicate that the cages were directly over the blasts. All 36 fish in the surface as well as the bottom cages were killed in the two experiments. In two controls, the 19 fish used were unharmed. Though only the two experiments were run it seems probable that Hercomite resembles dynamite in its lethal effects on fishes.

Black Powder Charges

Strikingly different results were attained as soon as black powder (FFG and FFFG) was tried and rather consistent evidence accumulated

TABLE 5
Fish Killed During Oil Exploration Under Permit From California Department of Fish and Game
September 4, 1951, to March 21, 1952

PL. Conception to San Mateo Point

Number of fish killed per shot	Number of open shots	Number of jetted shots	Total shots
0	2 332	508	2,840
1	1	2	3
9	1	0	1
20	1	0	1
200	0	2	2
Total number of shots	2,335	512	2,847
Total fish killed	30	402	432
Average kill per shot	0.013	0.79	0.15

A maximum of 45 pounds of Hercules FFFG black powder was used on all work during the month of September, 1951; revision of permit effective October 1, 1951, allowed a maximum of 90 pounds of powder on both open and jetted shots. In general the practice has been to use 40 pounds of powder on jetted shots and the maximum of 90 pounds on open shots.

as the experiments were continued (Table 4). Very few fish were killed either inside or outside the cages, even when the weight of the charges was increased to 45 pounds and some of the charges were fired on the bottom and others were exploded just below the surface—in positions where dynamite is often very destructive. In the subsequently resumed seismographic surveys, according to reports by the state observers, extremely few fish have been killed, even by charges up to 90 pounds (Table 5).

In 17 experiments (Nos. 45, 47–49, 53–59, 62–67), in which from 4 to 40 pounds of black powder were exploded after having been jettied into the bottom sediments 5 to 20 feet, not a single fish death, on the basis of stringent criteria (p. 345), was recorded either inside or outside the cages.

In the two trials (60 and 61) in which five pounds of black powder was exploded on the bottom none of the fish was killed in cages held only five feet away, or in the overlying surface cages, or in the surrounding water. In two similar experiments (51 and 52), in which the cage was held only 10 feet away from a 10-pound black powder explosion on the bottom, none of the fish were killed in one trial, but half in the two cages were destroyed in the other. No free-swimming fish were killed in these experiments.

Ten-pound and twenty-pound charges of black powder when exploded just below the surface (Exps. 50 and 46) killed no fish anywhere. Sub-surface explosions of 40 and 45 pounds (Exps. 41–44) varied in effect, depending apparently on either the type of container or the number of detonators employed. In two trials most of the fish in the surface cages were destroyed by 40-pound charges of black powder formed by binding together two sheet-metal containers five inches in diameter and 25 inches long, discharged by two detonators. Charges of similar weight in a shark-liver can with a single detonator caused no kill to caged fish only 20 feet from the explosion. That fish at somewhat greater distances are probably not killed by even such large charges of black powder is indicated by the fact that only one free-swimming fish, a mackerel, was destroyed in these four rigid tests. This was the only fish that was killed outside a cage in any of the 28 black powder experiments.

The resistance of fish to black powder explosions was dramatically exhibited in Exp. 54, in which 10 pounds of black powder exploded so close that the cage was badly damaged and partly covered with debris and the door was blown in (Figure 11). Though covered with mud, the two fish that failed to escape showed no signs of damage.

Effects of a jettied black powder shot are evident very soon—in about four or five seconds when the shot is in water about 30 feet deep. The large volume of suddenly generated gas carries mud and fine sand to the surface, forming a mushroom-shaped boil (Figure 12) that rapidly spreads over the surface. The resulting slick (Figure 13) usually has a diameter of 50 to 100 feet, depending on the size and depth of the charge. The amount of sand and mud that is brought to the surface seems to be relatively limited, for it forms only a superficial layer of murky water, below which clearer water can be observed. Jettied dynamite produces much less



FIGURE 11. Bottom cage damaged by 10-lb. black powder explosion No. 54. Remaining fish showed no damage. Photograph by William W. Rand, April, 1951.

FIGURE 12. Gas boil produced by a black powder explosion. Photograph by William W. Rand, April, 1951.

FIGURE 13. Slick following a black powder explosion boil. Photograph by William W. Rand, April, 1951.

11



12



13



gas and often no boil. The arrival of the shock wave from a dynamite explosion can be noted at a calm surface by the region of cavitation, which momentarily forms a small hump or dome.

In respect to both sound and shock the effects of black powder shots are relatively slight, as compared with explosions of dynamite or Herconite. Frequently the jetted shots are barely audible and in the launch are often missed entirely. Black powder shots near the surface produce spouts 50 to 150 feet high, according to the size of the charge, but generate much less noise than do similar dynamite or Herconite explosions.

The black powder explosions did not seem to have any conspicuous influence on the availability of game fish to sportsmen, as such fish were taken in the immediate vicinity soon after the shots were fired. They were apparently neither driven away nor deterred from feeding.

Explanation of Results

To explain the varied effects on fish life of underwater explosions it is desirable to examine and analyze individual components of the explosion complex, although, in general, the pattern of waves and other associated physical phenomena are quite complicated and, so far as we can learn, their interaction and the resultant forces are not completely understood. The most significant parameters are thought to be the amplitude (peak pressure), the type of compression wave, and rarefaction.

Underwater explosions produce two types of positive pressure waves, the initial compression or shock wave and the following bubble-pulse wave (Cole, 1948). The primary disturbance to the water during an explosion is caused by the arrival of the compression wave from the reacting explosive. Once initiated, the disturbance is propagated through the water as a pulse of compression with a leading front, which is steep (a shock front) or gentle, depending on the explosive used (Figures 8-9). The top of the pressure curve represents the peak pressure. In a uniform medium the peak pressure undergoes an exponential decay that is a function of the type of charge, its weight, and the distance from the charge. The peak pressure at a given distance is greater for larger weights, but increases only in proportion to the one-third power of the charge. The peak pressure from a given charge decreases with increasing distances. The rate of decay of energy varies with conditions. In open water the peak pressure from dynamite explosions is usually indicated as varying inversely as the 1.15 power of distance (not the 3.0 power assumed by Fitch and Young, 1948, p. 55). When the explosive is jetted into the bottom, the rate of energy decay is much greater. Data obtained during the experiments indicate that the approximate pressure near the bottom from jetted five-pound dynamite charges varies inversely as the 2.6 power of the distance (p. 345; Figure 10).

In either dynamite or black powder explosions the bubble pulse, shown at the right side in Figures 8 and 9, is relatively of long duration and low maximum pressure, without an abrupt front. In dynamite discharges, the bubble pulse has a maximum pressure far below that of the shock pulse. No indications were obtained that the bubble pulse from any of the explosions observed was of major significance in the destruction of fish.

The differential effects of dynamite and black powder explosions are attributable directly or indirectly to the abrupt shock wave produced by dynamite blasts. Dynamite detonates with a large and rapid evolution of

energy, attaining its maximum intensity almost instantaneously. Once started, the disturbance is propagated through the water as a pulse of compression with a very steep shock front (Figure 8). Hercomite, to judge from its effects on fish in two experiments, resembles dynamite in its action. Black powder, in contrast, burns more slowly and does not produce a shock wave with an abrupt front (Figure 9). Nor, with comparable charges, is the peak intensity nearly so high. The lethal threshold peak pressures from dynamite explosions varied in our tests from 40 to 70 p.s.i. (as measured by the research engineers of the United Geophysical Company), whereas peak pressures from black powder explosions as high as 124 to 160 p.s.i. (similarly measured) did not kill fishes in the experimental cages (Tables 2, 4). One obvious reason why fish are resistant to black powder explosions, even of high intensity, is their relative immunity to less than almost instantaneous pressure changes. In other experiments fish subjected by us rather slowly to hydrostatic pressures as great as 1,000 p.s.i. showed no apparent physical damage, even after a relatively sudden release of the pressure. Positive pressure in the range of 15 to 500 p.s.i. (one to 33 atmospheres), even though maintained for a 12-hour period, produced, so far as could be observed, little immediate effect and no lasting discomfort or pathology. Regnard (1884) found that freshwater fish whose air-bladder had previously been emptied of air showed no effect when a pressure of 100 atmospheres of pressure was applied to them.

The reason why a large decrease in the weight of a dynamite charge results in unexpectedly little reduction in the kill is that the peak pressure does not bear a linear relation to the weight of the charge, but, rather, varies as the one-third power of charge size. A five-pound charge, for example, yields about one-third the peak pressure that a 125-pound charge does. The usefulness of a charge for seismographic work does not decrease in direct proportion to its reduced weight, but, similarly, the fish-killing powers do not decrease in that ratio.

It seems probable that the peak pressure from the black powder explosions does not increase at as high a rate as does the pressure from dynamite blasts. E. Pat Shultz reports (in letter) that "With black powder increasing the charge size probably does not increase the peak pressure very much, but rather merely increases the duration of the pressure pulse. This is because the propagation rate of the burning is less than that of sound, and hence the full effect does not arrive at a distant point all at one time, as in a shock wave."

It was noted early in the experiments with dynamite that while fish in the surface cage were physically damaged by the blast, those in the bottom cage, nearest the explosion, often suffered no harm or less damage (Exps. 2, 3, 12, 14, 17, 19, 23, 25, 35). It was noted further that the free fish that were killed were mostly surface rather than bottom inhabitants. These observations can be explained in part only on the assumption that many bottom dwellers do not possess air-bladders and are therefore more resistant to explosions. Such bottom fishes as the kingfish, and others with large air-bladders, were found to be in the immediate area during some of the tests, but few were killed.

The greater mortality at the surface is probably caused by the intensity there of the rarefaction wave. It is assumed that, when reflected from the

surface of a less dense medium, as from the water-air interface, a compression wave, if of sufficient amplitude, assumes the opposite sign through change of phase and is thus transformed, with some loss of energy, into a negative-pressure pulse, called a rarefaction wave (Cole, 1948). The suddenly applied negative pressure (considering atmospheric pressure as the base of reference) is probably particularly deleterious, even though, as Cole (1948) indicates, negative pressures as great as one atmosphere are not likely to be realized in natural waters, because of the dissipation of energy through cavitation.

In a system involving much less rapid changes, a negative pressure of 25 inches of mercury applied for a period of 15 seconds has been held to kill a number of freshwater species having air-bladders (Hogan, 1940). Preliminary experiments by us indicate that marine fishes with an air-bladder are quickly killed by negative pressures of between 20 and 30 inches of mercury, whereas those without an air-bladder survive such treatment.

That suddenly applied negative pressures kill fish appears to be indicated by the outward explosion of the air-bladders. In a report published by the Chesapeake Biological Laboratory it is stated that "post mortem observation showed that the edges of holes in the swim bladder were turned outward and that blood from broken vessels in the wall of the bladder had been blown into the abdominal cavity" (Anonymous, 1948). Similar observations were independently made during the experiments just concluded. Dynamite-destroyed kingfish had the visceral cavity filled with gas, which had obviously been released, under some pressure, from the ruptured air-bladder, thereby rendering the fish buoyant.

Negative pressure may cause injury or death in part through the formation of bubbles in the body fluids. We assume, in particular, that negative pressure may liberate dissolved gases suddenly enough and in sufficient quantity to rupture the walls of unprotected blood vessels.

The deadliness of the rarefaction wave is doubtless greatest near the surface. The negative-pressure wave is propagated downward through the water, but becomes sharply attenuated with distance and tends to be cancelled by the increase in hydrostatic pressure and, at certain times and locations, by the simultaneous arrival of compression waves reflected from the bottom.

The difference in deadliness to fishes of dynamite and black powder explosions is presumably due in part to much higher negative pressures induced by dynamite. Cole (1948: 261) wrote that "in nearly all cases a negative absolute pressure is predicted for explosive waves of short duration." The wave from black powder blasts is of relatively long duration and low amplitude (Figures 8-9).

Large variations in fatalities in different cages may have been caused by the focusing of the path of the blast energy. The energy that is transmitted upward through the jet hole spreads out through the broad conical crater formed during the jetting (the craters were observed by diving). It is assumed that much of the energy emerging from the crater and from the surrounding bottom deposits is propagated through the water in a cone of similar form, leaving a shadow zone close to the bottom around the crater. The nine-cage unit was adopted in part to determine whether differential damage might be detected as a consequence of the directed energy. In Exp. 3, for example, there appears to have been such a focusing of

the energy, for the kill was differential, with no deaths in the bottom cage nearest the crater but complete mortality in the directly overlying cages (compare data in Table 2 with the cage diagram, Figure 7). The compression pulse, measured at the surface, was 148 p.s.i., well beyond the lethal threshold recorded in the experiments (40–70 p.s.i.). That the margin of the cone of high pressure may be sharp is suggested by certain experiments, for example Exp. 19, in which fish were unharmed in the bottom cage although a gauge attached to the top of this cage registered a peak pressure of 83 p.s.i., also within the usual fatal dose.

Great variation was observed in the damage to fish caused by the underwater explosions. The variable factors appear to include, among others, the type and amplitude of the pressure pulse, the kind of bottom, and the structure and size of the fish. It is obvious that no simple explanation could be offered for all of the varied results, even though knowledge of the physical phenomena associated with fish and with explosives were much more complete than it is. The knowledge at hand, however, allows us to reach some plausible inferences.

As the pathological conditions of hemorrhaging, burst air-bladders, and general disruption of the viscera are shown by dissection and as the sequence of events of an underwater explosion are rapid compression soon followed by rarefaction, it appears reasonable to suspect that compression suddenly applied and rarefaction are the factors that lethally damage fish, particularly those near the surface.

CONCLUSIONS AND SUMMARY

This investigation arose from a conflict between different interests involved in the exploitation of the marine resources of California. Seismographic exploration for submarine oil had been suspended, through the revocation of licenses, because the explosions had destroyed large numbers of fish. The purpose of the study was to determine if the explosives might not be handled in such a way, as through a reduction in the size of charge or through altered methods, that most of the danger of killing fish would be eliminated.

Large charges of such violent explosives as dynamite—say from 50 to 200 pounds—were known to be very destructive to fish life. Considerable areas can be more or less depopulated by repeated blasts, as indicated by operations observed in a submarine canyon. Repopulation, however, took place within a few months.

Charges even as small as ten, five, two and one-half, or one and one-quarter pounds often killed fish, even when the explosive had been buried many feet in the bottom sediments. The amount of loss varied and was difficult to assess completely. Hercomite appeared to resemble dynamite in its effect on fishes.

The lethal effects of small charges of dynamite is in agreement with expectation, since the peak pressure varies as the one-third power of the weight of the charge. For example, a one-pound charge produces one-half the pressure that an eight-pound charge does. The effect of even large explosions becomes dissipated with distance, quite rapidly when the charge is jetted. For five-pound jetted dynamite charges used in these trials the peak pressure near the bottom varied as the 2.6 power of the distance.

The effect of underwater explosions of such substances as dynamite if often intensified at the surface, where the positive compression wave is

reflected as a rarefaction wave. Fishes are very susceptible to negative pressures (that is, to pressures less than the atmospheric pressure). Black powder is much less effective than dynamite in producing such negative pressures.

Black powder explosions proved to be relatively innocuous in a series of experiments, even with charges as high as 20 to 45 pounds, whether the charge was buried in the sediments, resting on the bottom, or suspended near the surface. These results were rather unexpected, though consistent with other observations. The resistance of fish to even larger black powder explosions is obviously due to the relatively slow burning quality of this powder. Oscillograms showed that the energy from black powder explosions is not propagated on the very abrupt front that emanates from a dynamite blast. Resistance to very large and relatively rapid changes in positive pressure is a known attribute of fishes, but they cannot tolerate the almost instantaneous changes induced by high explosives. The rigidly construed lethal-threshold peak pressures from dynamite explosions, as measured by the research engineers, varied from 40 to 70 p.s.i. in our tests,² whereas peak pressures from black powder explosions as high as 124 to 160 p.s.i. did not kill fishes in the experimental cages. Indications were obtained that black powder discharges do not even drive fish away or prevent them from feeding.

The experiments strongly indicated that it would be safe to utilize even large charges (to at least 45 pounds) of black powder, as a source of energy for submarine seismographic surveys. Unknown and untested factors, including the size of the fish and of its air-bladder, led us to make some reservations in judgment—reservations that could best be tested during actual operations, by observing the effects of such explosions on free-swimming fishes of varied sorts and sizes. Such checking has been maintained and the reports of recent surveys support the view that the use of black powder in charges as large as 90 pounds will not cause excessive loss of fish.

It would therefore appear that the State is not confronted with a problem of oil *versus* fish. The evidence leads to the conclusion that exploration for oil can be continued without the undue destruction of fish life. A major conflict of interests in the exploitation of our marine resources seems to have been resolved.

² On the basis of less rigorous criteria of lethal effects, the reports of the Chesapeake Bay experiments (Anonymous, 1947, 1948) indicate a much higher lethal threshold for TNT explosions which, we understand, closely resemble dynamite explosions. On the theory that most fish severely injured by an explosion will in nature soon succumb through weakness, disease, or predation, we regard the more rigorous criteria as justified. Certainly it would not be safe to assume that internally injured fish will survive.

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FISH SPECIES MENTIONED

Only the vernacular names are used in the text. The species used in the 1951 experiments are marked by an asterisk (*), by a dagger (†), or by both, as explained on page 344. Some of these species and all those unmarked below, except the señorita, were killed in Scripps Submarine Canyon in 1950, as detailed in Table 1.

- *Pacific sardine, *Sardinops caerulea* (Girard)
- *Ocean northern anchovy, *Engraulis mordax mordax* Girard
- Panama bristlemouth, *Vinciguerra lucetia* (Garman)
- †Pacific saury, *Cololabis saira* (Brevoort)
- Kelp bass, *Paralabrax clathratus* (Girard)
- Sand bass, *Paralabrax nebulifer* (Girard)
- *†Grunion, *Leuresthes tenuis* (Ayres)
- †Jacksmelt, *Atherinopsis californiensis* Girard
- Kelp topsmelt, *Atherinops affinis cedrosensis* Hubbs
- *†Jack mackerel, *Trachurus symmetricus* (Ayres)
- *California pompano, *Palometa simillima* (Ayres)
- †Pacific mackerel, *Pneumatophorus japonicus diego* (Ayres)
- Sargo, *Anisotremus davidsoni* (Steindachner)
- *†Kingfish (tomcod croaker), *Genyonemus lineatus* (Ayres)
- *†Queenfish, *Seriophilus politus* Ayres
- Ocean whitefish, *Caulolatilus princeps anomulus* (Cooper)
- †Shiner seaperch, *Cymatogaster aggregata* (Gibbons)
- Pink seaperch, *Zalembius rosaceus* (Jordan and Gilbert)
- Buttermouth seaperch, *Embiotoca* sp.
- †White seaperch, *Phanerodon furcatus* Girard
- Sharpnose seaperch, *Phanerodon atripes* (Jordan and Gilbert)
- Rubberlip seaperch, *Rhacochilus torotes* Agassiz
- Pile perch, *Damalichthys rupea* Girard
- Blacksmith, *Chromis punctipinnis* (Cooper)
- Garibaldi, *Hypsypops rubicunda* (Girard)
- California sheephead, *Pinctometopon pulchrum* (Ayres)
- Opaleye, *Girella nigricans* (Ayres)
- Señorita, *Oxyjulis californica* (Günther)
- Bocaccio, *Sebastes paucispinis* (Ayres)
- Bass rockfish, *Sebastes serranoides* Eigenmann and Eigenmann
- Vermilion rockfish, *Sebastes rosaceus* (Girard) (= *S. miniatus*)
- Kelp rockfish, *Sebastes atrovirens* (Jordan and Gilbert)
- Widow rockfish, *Sebastes ovalis* Ayres
- Spotted rockfish, *Sebastes hopkinsi* Cramer
- Halfband rockfish, *Sebastes semicinctus* Gilbert
- Speckled rockfish, *Sebastes umbrosus* (Jordan and Gilbert)
- Rosy rockfish, *Sebastes* sp. (= *S. rosaceus* of recent authors)
- Greenspotted rockfish, *Sebastes chlorostictus* (Jordan and Gilbert)
- Pink rockfish, *Sebastes eos* Eigenmann and Eigenmann
- Starry rockfish, *Sebastes constellatus* (Jordan and Gilbert)
- Spanishflag, *Sebastes rubrivinctus* (Jordan and Gilbert)
- Striped rockfish, *Sebastes elongatus* (Ayres)
- Brown rockfish, *Sebastes auriculatus* (Girard)
- Whitebelly rockfish, *Sebastes verillaris* (Jordan and Gilbert)
- Calico rockfish, *Sebastes dalli* (Eigenmann and Beeson)
- Treefish, *Sebastes serripes* (Jordan and Gilbert)
- Rockfish (species?) ; very young, *Sebastes* sp.
- †Kelp pipefish, *Syngnathus californiensis* Storer
- Crested goby, *Coryphopterus nicholsi* (Bean)
- Zebra goby, *Lythrypnus zebra* (Gilbert)
- Northern midshipman, *Porichthys notatus* Girard
- †Slim midshipman, *Porichthys myriaster* Hubbs and Schultz
- Spotted eusk-eel, *Otophidium taylori* (Girard)

REVIEW OF THE CALIFORNIA SARDINE FISHERY¹

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INTRODUCTION

In terms of many of our well known world fisheries the sardine industry along the Pacific Coast of North America is relatively young. It had its beginnings about 1916 with the increased demand for food during the first World War. As long as the fishery yielded the required tonnages, which in the later years was 400,000 tons or more each season it commanded no undue comment from the fishing industry or from the public in general. After 1945-46, when the total landings dropped rapidly below this figure all attention was focused on this one fishery. Many reasons have been advanced for the failure of the fishery and many suggestions have been made for its rehabilitation. Through the efforts of the industry, sardine investigations have been greatly expanded and Scripps Institution of Oceanography, Hopkins Marine Station and California Academy of Sciences have recently joined in the study which had been initiated by the California Department of Fish and Game in 1919, extended by the Fisheries Research Board of Canada and the Province of British Columbia in 1929, by the U. S. Fish and Wildlife Service in 1937 and the Washington Department of Fisheries and the Fish Commission of Oregon in 1938.

The importance of this fishery to California alone justifies an even greater expansion of these investigations. In this State the fishery is maintained by a fleet of 250 to 300 purse seine vessels manned by approximately 3,000 fishermen. Over 100 processing plants located at San Francisco, on Monterey Bay and in Los Angeles, Newport and San Diego harbors receive the catch and convert it into canned sardines which are shipped throughout the world, or reduce the fish to meal and oil. The meal finds its chief use as a supplemental feed for livestock and poultry. The oil is used for a multitude of purposes, including edible products.

TONS IN THE CATCH

Although the major part of the sardine catch has been taken by California fishermen and processed in California plants, during some seasons this fishery has also made an important contribution to the economy of British Columbia, Washington, and Oregon. The California seasonal catch in 1916-17 was less than 30,000 tons. From this modest beginning it increased rapidly and 20 years later had expanded to over 700,000 tons. In British Columbia this same fish, there termed pilchard, was first taken in appreciable numbers about 1926 and 10 years later Washington and Oregon entered the fishery. In these Pacific Northwest areas the chief

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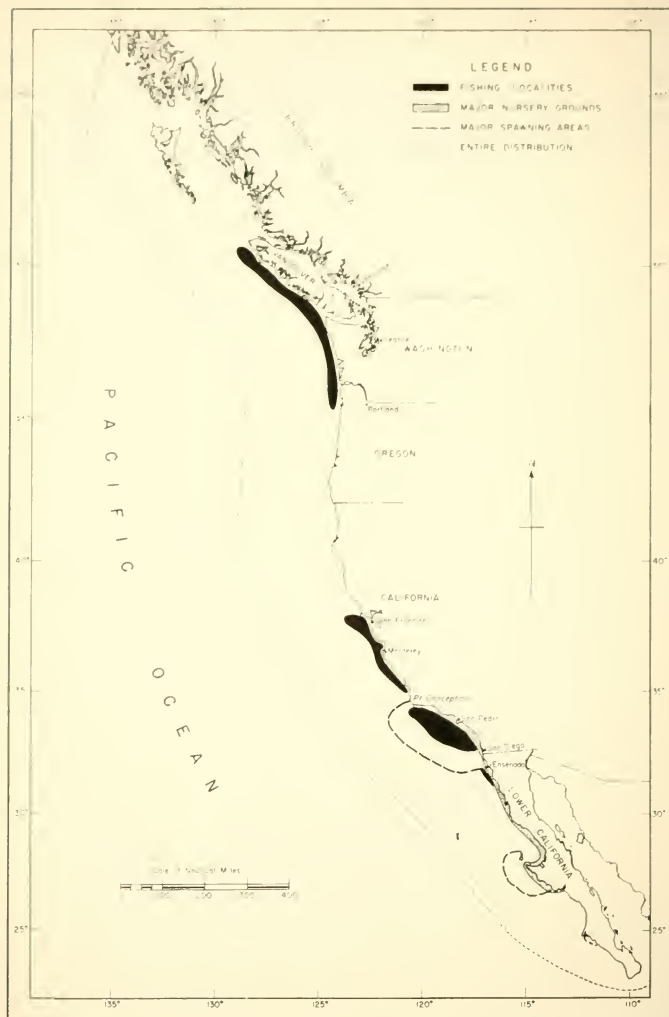


FIGURE 1. Map showing diagrammatically the distribution of the sardine, the major spawning areas, the chief nursery grounds and the fishing grounds. The size of the fishing area in each locality bears no relation to the amount of fish caught in the different localities.

use of the sardine has been reduction into meal and oil. With the development of the northwest fisheries and the rapid expansion in California the total catch reached an all-time high of 790,000 tons in 1936-37. In the succeeding eight seasons it fluctuated around 500,000 to 600,000 tons, then dropped to 440,000, 250,000 and 130,000 tons in three successive seasons (Table 1). No fish have been taken in the Pacific Northwest since 1948-49 but by 1950-51 the California catch had increased to 350,000 tons. In the next season, 1951-52, however, the California catch experienced a new decline to less than 130,000 tons.

The proportion of the California catch that has been reduced into meal and oil has varied from season to season depending on the relative value of meal and oil as compared with canned fish. It is not possible to arrive at an absolute figure of the tonnage used for canning and for reduction since these proportions vary between plants, between seasons and between months. Table 2 gives, however, the most accurate records available. The first three columns of this table show the cleaned weight of fish placed in the cans, the weight of offal from these cleaned fish and "overage" or weight of whole fish received for canning but actually reduced into meal and oil.²

The next three columns show the tons reduced under permit.³ Between 1931-32 and 1938-39 floating reduction ships operated off San Francisco beyond the three-mile limit and thus beyond the jurisdiction of California laws. For simplicity their tonnages are included in the above heading although they operated without permit. Prior to 1932-33 meal and oil produced by shore plants was used for edible purposes.

The seventh column headed "miscellaneous" includes the small amounts of sardine taken each season for smoking, salting, pet food, etc. The totals of Table 2 do not agree with those of Table 1 since the latter also include poundages sold to fresh fish dealers for dead bait and for human consumption in a fresh state. In addition to the tonnages given in Tables 1 and 2 sardines are taken in California for use as live bait. Records of the tonnages so used for marine sport fishing in Southern California have been collected since 1939, with the exception of the war years 1942 to 1945, and are given in Table 3. It has not been possible to obtain any accurate record of the tonnages used for live bait in the commercial fisheries.

The total landings as shown in Tables 1 and 2 would indicate that the sudden disaster that overtook the sardine industry had come without warning. This is not true, however, for the first danger signs were evident in 1937-38 when the fishermen experienced much difficulty in finding schools of fish and the total catch in California dropped from the all-time high of 726,000 tons in the 1936-37 season to less than 420,000 tons. Even earlier than this, in 1935-36 and 1936-37, the average monthly catch of the fishermen began to decline (Clark and Daugherty, 1950). After 1937-38 this decline in total catch and in average monthly catch stopped temporarily and for the next eight years total landings and average monthly

² California law requires that $13\frac{1}{2}$ cases of pound oval cans, or equivalents, be produced from every ton of sardines canned. If all sardines are in good condition 20 or more cases can be produced. The overage consists, therefore, of broken and soft fish and at times fish fit for canning but more valuable as meal or oil.

³ Since 1932 California law has allowed the granting of permits to processing plants for the reduction of whole sardines into meal and oil. The tonnages so granted have varied from year to year.

TABLE 1
Seasonal Catch in Tons^a of Sardines Along the Pacific Coast—Each Season Includes
June Through the Following May

Season	British Columbia	Washington	Oregon	Total Pacific northwest	California					Grand total	California percent of total
					Floating plants	San Francisco	Monterey	San Pedro	San Diego		
1916-17				80			7,710	17,380	2,440	27,530	100
1917-18							23,810	41,310	7,360	72,660	100
1918-19	3,640			3,640		430	33,750	32,330	6,810	73,180	95
1919-20	3,280			3,280		1,000	13,040	16,580	6,410	70,310	95
1920-21	4,400			4,400		230	24,960	11,740	1,520	42,830	90
1921-22	990			990		80	16,290	19,220	910	36,500	97
1922-23	1,020			1,020		110	20,210	33,170	2,620	66,130	98
1923-24	970			970		190	45,920	35,040	2,780	84,900	99
1924-25	1,370			1,370		560	67,310	96,330	8,820	174,300	99
1925-26	15,950			15,950		560	69,010	61,990	5,710	137,270	90
1926-27	48,500			48,500		3,520	81,860	64,720	2,110	152,210	76
1927-28	68,430			68,430		16,690	98,020	67,300	4,650	187,260	73
1928-29	80,510			80,510		13,520	120,290	119,250	1,120	254,180	76
1929-30	86,340			86,340		21,960	160,650	140,540	2,620	334,990	79
1930-31	75,070			75,070	10,960	25,970	109,620	38,490	80	260,130	71
1931-32	73,600			73,600	31,040	21,610	69,080	42,660	260	164,650	69
1932-33	44,350			44,350	58,790	18,630	89,600	83,600	60	250,680	85
1933-34	4,050			4,050	67,820	36,340	152,480	125,050	1,750	383,440	99
1934-35	43,000			43,000	112,040	69,000	230,860	178,820	4,860	593,580	93
1935-36	45,320	10	26,230	71,560	150,830	76,150	184,470	138,400	10,650	560,500	89
1936-37	44,450	6,560	14,200	65,210	235,610	141,100	206,710	138,110	4,590	726,120	92
1937-38	48,080	17,100	16,660	81,840	67,580	133,720	104,930	109,940	380	416,560	84
1938-39	51,770	26,480	17,020	95,270	43,890	201,200	180,990	146,400	2,780	670,530	86

1939-40	5,520	17,760	22,330	45,610	212,450	227,870	101,820	110	542,250	587,860	92
1940-41	28,770	810	3,160	32,740	118,090	165,700	175,590	1,200	460,580	493,320	93
1941-42	60,050	17,100	15,850	93,000	186,590	250,290	148,910	1,580	587,370	680,370	86
1942-43	65,880	580	1,950	68,410	115,880	184,400	201,510	2,870	504,660	573,070	88
1943-44	88,740	10,440	1,820	101,000	126,510	213,620	135,310	2,690	478,130	579,130	83
1944-45	59,120	20		59,140	136,600	237,250	178,290	2,770	554,910	614,050	90
1945-46	34,300	2,310	90	36,700	84,100	145,520	173,110	950	403,680	440,380	92
1946-47	3,990	6,140	3,960	14,090	2,870	31,240	194,720	4,770	233,600	247,690	94
1947-48	490	1,360	6,320	8,780	90	17,630	101,150	2,460	121,330	130,110	93
1948-49		50	5,320	5,370	110	47,830	131,860	3,920	183,720	189,090	97
1949-50					16,090	130,990	187,260	3,280	337,620	337,620	100
1950-51					12,730	19,100	318,350	2,910	353,090	353,090	100
1951-52					80	640	126,460	1,350	128,530†	128,530†	100

* Data for British Columbia were supplied by the Canadian Bureau of Statistics and the Province of British Columbia, those for Washington by the Washington Department of Fisheries and for Oregon by the Fish Commission of Oregon. Tonnages delivered to the floating plants were compiled by the United States Fish and Wildlife Service from the books of the companies operating off the California coast. California landings were derived from the records of the California Department of Fish and Game.

† Totals for 1951-52 are preliminary and subject to minor changes.

TABLE 2
Utilization of Sardines
Tons Used by California Processing Plants

Season	Tons received for canning			Tons reduced under permit			Tons total reduced and average	Tons misused and lost ²	Tons processed ³ grand total
	Canned cleaned weight	Offal	Total canned and offal	Overage	Tons reduced under permit				
					Shore plants	Floating ¹ plants			
1927-28	65,446	65,447	130,893	6,742	43,321*		43,321	50,063	181,176
1928-29	74,307	74,306	148,613	15,277	88,092*		88,092	103,369	252,433
1929-30	103,856	103,856	207,712	24,444	90,380*		90,380	114,824	322,600
1930-31	54,224	53,568	107,792	16,650	47,487*	10,963	58,450	75,100	182,964
1931-32	41,793	41,809	83,602	15,850	31,739*	31,045	62,784	78,634	162,365
1932-33	20,432	20,765	41,197	19,406	129,004	58,789	187,793	207,289	248,965
1933-34	48,931	48,923	97,854	45,833	170,068	67,824	237,892	283,725	381,696
1934-35	46,897	46,889	93,786	44,323	342,350	112,045	454,395	498,718	592,791
1935-36	80,245	80,323	160,568	76,960	168,952	150,827	319,779	396,748	557,993
1936-37	74,642	74,643	149,285	63,007	274,258	235,611	509,869	572,876	723,752
1937-38	57,491	57,490	114,981	45,947	183,858	67,578	251,436	297,383	413,412
1938-39	64,344	64,344	128,688	56,169	337,846	43,889	381,738	440,907	572,465
1939-40	78,372	78,372	156,745	68,612	303,426		303,426	372,038	531,878
1940-41	77,892	77,892	155,784	70,404	223,587		223,587	293,991	434,709
1941-42	128,835	128,835	257,670	108,622	211,625		211,625	320,247	583,463
1942-43	92,615	92,615	185,231	86,472	229,334		229,334	315,806	501,341
1943-44	78,745	78,745	157,490	74,037	241,733		241,733	315,770	473,522
1944-45	91,411	91,411	182,822	82,545	277,098		277,098	359,613	548,415
1945-46	93,732	93,732	187,464	70,533	137,867		137,867	298,400	396,060
1946-47	67,956	67,956	135,912	47,973	43,367		43,367	91,340	227,716
1947-48	36,636	36,636	73,272	19,723	13,126		13,126	32,849	110,237
1948-49	63,619	63,619	127,237	16,890	8,157		8,157	159,848	7,364
1949-50	105,755	105,755	211,510	68,274	44,216		44,216	112,490	335,572
1950-51	114,128	114,127	228,255	83,163	36,487		36,487	119,650	355,160
1951-52	55,934	55,934	111,868	9,224	1,022		1,022	10,240	126,541

* Used for edible fish meal and flour.

¹ The floating reduction ships operated off shore and therefore without permit. Their tonnage is included here for simplicity.

² Includes tons used for salting, smoking and pet food.

³ Processed fish only. Does not include sardines used fresh or for live bait.

TABLE 3
Tons of Sardine Taken for Sport Fishing in the Southern California Live Bait Fishery

Year	Tons	Year	Tons
1939	573	1947	736
1940	336	1948	543
1941	153	1949	1,873
		1950	1,549
1946	668	1951	1,301

catch remained relatively constant. Then in 1945-46 came the disastrous decrease in sardine landings which had a much greater impact on the Pacific Northwest and Central California fisheries than on those of Southern California. The explanation of this decline and of the greater disaster in the north involves an understanding of the biology of the sardine.

BIOLOGY

The Pacific sardine (*Sardinops caerulea*) occurs from southeastern Alaska southward to the tip of Baja California and into the Gulf of California. The spawning season is in the spring and early summer months and the major spawning areas lie offshore outside the Channel Islands of Southern California and off the central part of Baja California. In some seasons, however, spawning occurs over a much greater range and at least as far north as the Pacific Northwest. In general, spawning is confined to waters of 54.5 degrees to 60.8 degrees F. (California Co-operative Sardine Research Program, 1950.)

The young fish during their first year are found fairly close to shore off central and northern Baja California and off Southern California. By the end of their first year they have evidenced a slight northward movement and in each succeeding year this northward migration becomes more pronounced. These northward movements occur during the summer months and a return southward takes place in the late fall and winter (Clark and Janssen, 1945).

As a rule the one- and two-year-old sardines are not found in any numbers north of Central California and the largest and oldest fish comprise a high proportion of the catch in the Pacific Northwest (Felin *et al.*, 1948, 1949, 1950, 1951). These older sardines which have made the longest northward journey during the summer do not return to the San Francisco, Monterey, and Southern California fishing grounds until the winter months (Clark and Janssen, 1945). This explains why sardines taken in the Pacific Northwest are chiefly large fish and why that is a summer fishery whereas the California fishery concentrates in the fall and winter months, and why the larger sardines are not taken in California in appreciable numbers until about December.⁴

⁴ The California sardine season is fixed by law and fishing is permitted in Central California from August 1st through January 15th and in Southern California from October 1st through February 1st. Before there was a fixed season, however, not enough sardines were found on the California grounds during the summer months to make fishing profitable.

One of the most striking features of the biology of the sardine is the marked variation in survival of the young fish resulting from each season's spawning. Some year classes have been exceptionally abundant, others very sparse. These exceptionally dominant groups have been evident in the fishery since the investigations were begun in 1919 (Higgins, 1926; Scofield, 1926; Thompson, 1926), but until a method of age determination had been developed it was not possible to define the dominant groups in terms of specific year classes.

Since 1941-42, by detailed examination of the scales, it has been possible to calculate the numbers of sardines of each age class taken in each season's catch. These age determinations indicate that fish spawned in 1939, and known as the 1939 year class, constituted the largest single year class in the population during the past 10 years. This group was more than twice as abundant as the average for this time interval. Sardines spawned in 1938 were above average in abundance, the 1940 and 1947 classes were a little better than average and the 1942 class of about average abundance. The remaining six year classes were poorer than average and the 1944 and 1945 groups much below average (Clark and Daugherty, 1952, Table 9).

This marked variation in survival of young sardines from each season's spawning accounts in a large measure for the failure of the fishery in the more recent years. During the seasons 1941-42 through 1943-44 the fishery was chiefly maintained by the 1938, 1939, and 1940 year classes and these three groups made material contributions to the fishery in 1944-45 and 1945-46. By 1946-47 these older fish were no longer found on the fishing grounds and the numbers of sardines in the six year classes, 1941 to 1946, were too few to support a major fishery (Figure 2). The more abundant 1947 and 1948 classes resulted in a partial recovery of the fishery in 1949-50 and 1950-51 but their numbers were not great enough to maintain good fishing beyond two seasons, nor were they of sufficient size and age to reach the northern fishing grounds. Hence the recovery in these two seasons was of material benefit to the Southern California fishery only and a slight aid to the Monterey fishery.

PRESENT STATUS OF THE POPULATION

At present, as indicated by Figure 2, the sardine fishery is dependent on not more than three age groups at any one time and in the past three seasons, 1949-50 through 1951-52, 70 to 80 percent of the catch has come from only two, the 1947 and 1948 year classes. With the concentration of the entire fishing pressure on two age groups, fish that are only two and three years old, no year class can support the fishery for many seasons unless its abundance is far above average, nor will enough fish of any year class grow to sufficient size to produce good fishing on the northern grounds.

In the earlier years there were many older sardines, representing many different age groups, on the fishing grounds. These carried the industry through the seasons when few fish survived from the annual spawning. Now, with the fishery depending on only one or two age groups, great fluctuations in the total landings occur from season to season. When these one or two year classes are of average abundance, seasonal tonnages of 200,000 to 300,000 may be caught. If these year classes are

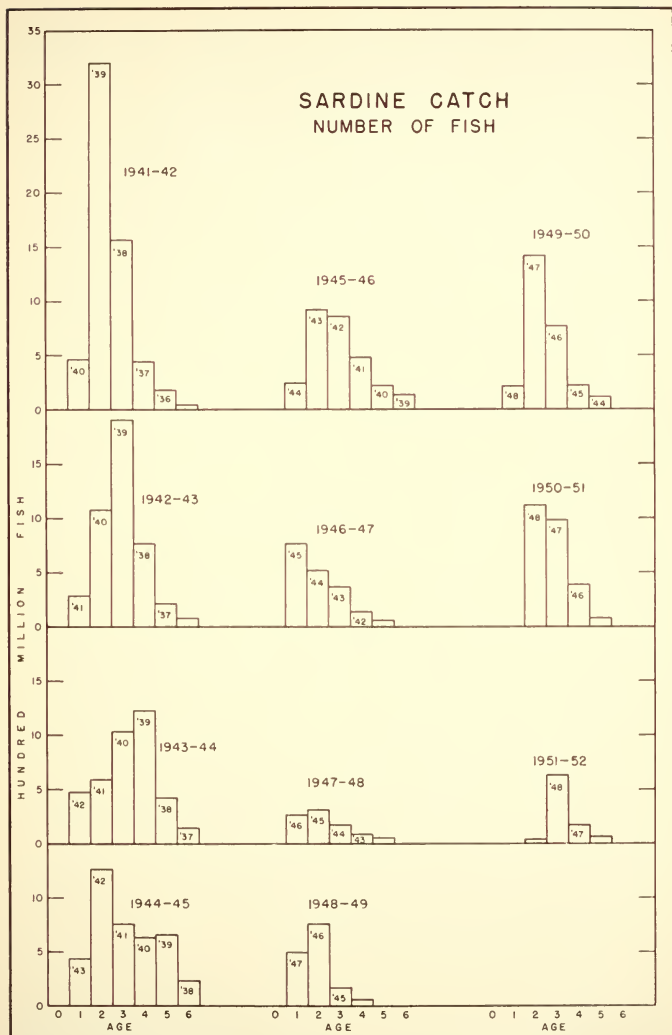


FIGURE 2. Seasonal age composition in numbers of the sardine catch off California and the Pacific Northwest

TABLE 4
Numbers of Sardines by Age Used by the Pacific Coast Processing Plants, 1941-42 Through 1951-52
(Numbers of fish are given in thousands, i.e., 000 omitted)

	Age											Total
	0	1	2	3	4	5	6	7	8	9	10	11
1941-42												
Pacific Northwest	11,161	239,116	102,308	162,670	114,950	37,429	20,290	10,430	3,419	909	2,018	704,700
California	455,186	2,957,148	1,556,959	282,009	69,214	10,664	3,736	889				5,335,805
Pacific Coast	466,347	3,196,264	1,659,267	444,679	184,164	48,093	24,026	11,319	3,419	909	2,018	6,040,505
1942-43												
Pacific Northwest	3,248	46,688	181,163	57,565	50,466	28,024	6,334	3,248	548		1,095	378,579
California	281,564	1,030,746	1,724,510	707,087	160,034	51,968	8,230	791				3,964,840
Pacific Coast	284,812	1,077,434	1,905,673	764,652	210,500	79,992	14,764	3,949	548		1,095	4,343,419
1943-44												
Pacific Northwest	2,788		66,306	210,453	106,657	65,808	25,143	7,437	2,165	638		188,333
California	473,828	596,690	964,728	1,018,030	318,675	82,497	19,254	2,836	1,104			3,477,702
Pacific Coast	476,616	596,690	1,031,034	1,228,483	425,332	148,305	44,397	10,273	3,629	638		3,966,035
1944-45												
Pacific Northwest	7,107	18,798	10,163	59,425	103,618	47,223	13,703	6,088	1,529	509		268,163
California	423,999	1,242,181	747,102	582,139	551,206	190,114	59,315	11,449				3,807,805
Pacific Coast	431,106	1,260,979	757,265	641,564	654,824	237,637	73,018	17,537	1,529	509		4,075,968
1945-46												
Pacific Northwest	1,962	14,245	19,691	2,973	36,157	51,285	23,472	6,413	1,479			157,677
California	245,968	909,374	837,888	479,311	197,362	93,881	39,702	10,083	1,016			2,805,585
Pacific Coast	247,930	923,619	857,579	482,284	233,519	145,166	54,174	16,496	2,495			2,963,262
1946-47												
Pacific Northwest			2,647	6,371	6,112	26,001	16,941	2,393	1,462			61,927
California	3,056	762,109	520,171	366,371	135,871	50,091	8,892	6,473	1,360			1,855,557
Pacific Coast	3,056	762,109	520,171	369,018	142,242	56,203	34,893	23,414	3,753			1,917,484

1947-48											
Pacific Northwest											
California											
28,448	828	19	773	7,104	3,927	4,824	8,959	7,290	1,326	102	37,184
	258,375	314,142	171,176	88,882	49,290	12,725	2,931	1,315	194	10	927,488
Pacific Coast											
28,418	259,203	314,161	171,949	95,986	55,217	17,576	11,800	8,614	1,520	112	964,676
1948-49											
Pacific Northwest											
California											
721	499,800	759,244	163,918	57,936	16,020	2,132	3,284	4,808	1,876	116	22,281
											1,499,851
Pacific Coast											
721	499,800	759,362	164,152	59,480	21,181	7,292	3,284	4,808	1,876	116	1,522,132
1949-50											
California											
	215,496	1,416,150	768,542	225,782	111,136	12,857	1,106	1,808	965	290	2,754,132
1950-51											
California											
		1,121,365	989,773	388,376	73,900	15,651	362	60		19	2,589,569
1951-52											
California											
	10,378	49,122	643,212	175,735	61,552	14,580	2,560	274			957,413

* After Felin, et al. No sardines taken in the Pacific Northwest after 1948-49.

below average, the total landings will decrease correspondingly and may drop to approximately 100,000 tons, as occurred in 1951-52, or even less. If one or two outstandingly abundant year classes should be produced the total catch might show a spectacular increase for a few seasons. With the present intense fishing effort these high seasonal totals will not be maintained, however. They might last for one season, for two or three but sooner or later the industry would have to expect another decline and perhaps a rapid one.

The immediate future for even the Southern California fishery is not bright. Data now at hand indicate that 1949, 1950, and 1951 year classes are below average in abundance and offer little promise of material contributions to the fishery; therefore, no immediate increase in total landings can be expected and a further decline is anticipated.

MANAGEMENT

There is no simple solution to the present dilemma: how to bring about a recovery of the Pacific Coast sardine industry. As the studies of conditions in the ocean continue it is hoped that the reasons for success or failure of spawn survival will become known but there is little hope of developing methods to improve conditions in the sea and thus assure adequate recruitment of younger sardines each season. Without adequate annual recruitment and with the fishery dependent on two or three year classes, there will continue to be good and bad years in Southern California and there is little promise that Central California or the Pacific Northwest can expect any good fishing seasons.

If a method could be devised to relieve the present fishing pressure and thus give the sardines an opportunity to grow to a large size and an older age, the northern fisheries would be benefited. This should also produce a backlog of older fish to carry the industry through the lean years that result when spawn survival is less than average.

There is some suggestion that the most abundant year classes have been produced when oceanic conditions were favorable for spawning along a large portion of the Pacific Coast. With the present scarcity of larger and older sardines in the population and the resultant lack of sardines in the more northern waters, spawning may not be widely dispersed even though conditions are favorable. Thus the lack of older fish may be a contributing factor in the failure to produce good year classes in the more recent years and may tend to prevent appreciable population recovery.

The present heavy fishing pressure on one-, two-, and three-year-old sardines is also unsound because many fish are required to produce a ton. A one-year-old sardine will average 7.7 inches in total length, a two-year-old 9.1, and a three-year-old 10.0 inches (Phillips, 1948). A catch of one-year-old sardines will consist of 14,000-16,000 fish per ton, of two-year-olds 8,000-10,000, and three-year-olds 6,000-7,000 fish (Table 4). Thus a fishery taking a greater portion of its catch from sardines three and more years old will place much less strain on the population than a fishery concentrating on one- and two-year-olds. Assuming a natural mortality of 20 percent, which is the most reasonable average figure

TABLE 5

Number of Sardines per Ton at Each Five Millimeters and at Each Half Inch and Average Weight per Fish

Total length inches	Standard length mm.	Fish per ton	Av. wt. per fish ounces	Total length inches	Standard length mm.	Fish per ton	Av. wt. per fish ounces
4.6 -----	100	111,000	0.3	9.3 -----	200	8,000	4.0
	5	77,000	0.4		5	8,000	4.0
5.1 -----	110	67,000	0.5	9.7 -----	210	7,000	4.6
	5	50,000	0.6		5	7,000	4.6
5.6 -----	120	43,000	0.7	10.2 -----	220	6,000	5.3
	5	38,000	0.8		5	6,000	5.3
6.0 -----	130	34,000	0.9	10.7 -----	230	6,000	5.3
	5	30,000	1.0		5	6,000	5.3
6.5 -----	140	28,000	1.1	11.1 -----	240	5,000	6.4
	5	25,000	1.3		5	5,000	6.4
7.0 -----	150	23,000	1.4	11.6 -----	250	5,000	6.4
	5	20,000	1.6		5	4,000	8.0
7.4 -----	160	19,000	1.7	12.1 -----	260	4,000	8.0
	5	16,000	2.0		5	4,000	8.0
7.9 -----	170	15,000	2.1	12.5 -----	270	4,000	8.0
	5	13,000	2.4		5	4,000	8.0
8.3 -----	180	12,000	2.7	13.0 -----	280	3,000	10.7
	5	11,000	2.9		5	3,000	10.7
8.8 -----	190	10,000	3.2	13.5 -----	290	3,000	10.7
	5	9,000	3.6				

available for the sardine, any year class will gain more in weight than it will lose through natural causes until it is three or four years old. For these reasons the burden of the fishery should rest on fish four years and older.

To bring about the desired increase in the numbers of older and larger sardines in the population will require a sacrifice on the part of the sardine industry. Some means will have to be devised to hold the catch at a level low enough to permit a longer life expectancy for each year class than now occurs. To devise such a method is not simple, however. With a migratory species closed areas offer no solution. Size limits have been tried and have not proved practical in a purse seine fishery since enforcement of such regulations is extremely complex and many undersized fish are killed at sea. The present closed season has done nothing to curtail the total catch and any adequate limitation would require a fishing season so short it would be ruinous. With the present fishing fleet and plant capacities, over 100,000 tons have been taken in a month's fishing on eight occasions during the past 10 seasons and a maximum month's catch of 190,000 tons occurred in October, 1944.

A fixed total tonnage, commonly termed a seasonal bag limit, would hold the total catch to the desired level but methods of allotment are complex and without allotment the industry might be thrown into chaos. The final decision about satisfactory management methods should rest with the industry. It has the most to gain if a constructive management program can be developed and the most to lose if no solution is reached.

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THE DECLINE OF THE PACIFIC MACKEREL FISHERY¹

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HISTORY OF THE FISHERY

With the attention of the fishing industry focused on the spectacular failure of the California sardine, an equal if not greater decline in the Pacific mackerel fishery has gone almost unnoticed. This decline has been further obscured by the expansion of the jack mackerel fishery.

Prior to 1928, the Pacific mackerel (*Pneumatophorus diego*) fishery was conducted almost exclusively for the fresh fish trade. Since that year, with the exception of depression years 1930, 1931, and 1932 the demand for mackerel for canning purposes has been practically unlimited. This fishery was at first prosecuted largely by net boats (lamparas, gill nets, ring nets and purse seines), but in the 1939-40 fishing season² scoop boats caught more Pacific mackerel than did the net boats. The scoop fleet continued to catch the majority of fish until 1947-48 when net boats again landed the greater tonnage. This was also true in 1950-51 and preliminary figures indicate that net boat landings during the current 1951-52 season will again surpass the scoop catch. Until 1935-36, when over 146,000,000 pounds of Pacific mackerel were taken in California, the trend of the catch was upward; since that season there has been a slow but steady decline in landings to the 32,000,000 low of 1951-52.

From 1928 to 1934, most of the catch was made by boats of less than 50 feet over-all length. These boats fished within a few hours of their home port and many of the nets used were not over 15 fathoms deep. Few had means of communicating with each other while fishing. If a skipper located an area in which fish were abundant he could, by not telling his competitors, sometimes fish the same area for a week before the other skippers could find where he was catching his fish. Croker (1933 and 1938) gives a detailed history of the mackerel fishery.

After 1934 a majority of the net boats in the fishery were over 50 feet in length, some nearly 100 feet. Those boats built within the last seven years have tended to be of two types: the "baby purse seiner," around 50 feet in length, and very large purse seiners over 80 feet in length (Daugherty, 1952).

The small boats represent a smaller investment and require a smaller crew, and so in spite of their more limited cruising range and carrying capacity often pay off as well or better during periods when fish are scarce. Conversely, as fishing has become poorer many larger seiners have been built and equipped to go farther afield. Thus, when not fishing for mackerel and sardines, these boats often go in search of tuna off the coasts of Central and South America.

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² The mackerel fishing season extends from May 1st through April 30th.

Many devices have been incorporated as standard equipment on the present day purse seiner. The principal purpose of these is to speed operations and at the same time make the work easier and more efficient. Such items as a purse line on the cork line, steel cable purse lines, chain lead lines, the "stick," dragger winches, depth sounders, radio telephones and motor skiffs are included. As pulling nets by hand is no longer necessary, these nets, in many instances, have been made longer and deeper and therefore fish a larger area. Since 1945, installation of depth sounders on nearly all of the boats has made it unnecessary to have a school of fish "flare" at the surface before it could be located and set on. Finally, installation of radio telephones has made it possible to communicate with any other boat in the fleet or with shore installations, and when fish are found relatively abundant in a limited area friends can be contacted immediately and most of the fish caught before they can move to another area.

This constantly increased pressure on the Pacific mackerel schools has undoubtedly been instrumental in helping reduce their numbers to the low levels of today. Too, failure of the sardine (*Sardinops caerulea*) fishery in the past five years has hurried the inevitable end of the Pacific mackerel fishery. Boats which would normally have been happily engaged in sardine fishing at Monterey, San Francisco, and other northern ports moved to the Los Angeles Harbor area, center of the California mackerel fishery, and added their numbers to an already over-large fleet of seiners. Both jack mackerel (*Trachurus symmetricus*) and sardines are fished in the same waters as Pacific mackerel and all three species are used for canning. As a result, the purse seiners are actually fishing for one of three species but will substitute either of the other two if acceptable to the cannery. Thus prosecution of the Pacific mackerel has continued unabated even though fishing for this species alone would no longer be profitable.

Even when the schools of mackerel are so small the seiners will not set their nets on them they are still fair prey for the 500 or more small boats which fish for mackerel with scoop nets. As has been mentioned previously these scoop boats, though individual loads seldom exceed three or four tons, actually landed the major portion of the catch during more than four-fifths of the years since 1939 when scoop boats started operating on a large scale. Crews on these scoop boats vary from one to three men. Boat lengths seldom exceed 30 feet. Fishing, usually carried on at night, is conducted within a few miles of the mainland or around Santa Catalina Island. In scoop fishing, ground fish or "chum" is thrown into the water. Mackerel thrash about after this food and as many as 30 or 40 can be dipped in one scoopful.

AGE COMPOSITION OF THE CATCH

The age composition of the Southern California catch of Pacific mackerel was recently determined for the 12-season period 1939-40 through 1950-51 (Fitch, 1951). These fish were aged by means of otoliths, pairs of bones which make up part of the inner ear. Other structures including scales, from which the ages of fish can be determined proved unsatisfactory for aging Pacific mackerel.

Sampling of the Pacific mackerel catch has been conducted since July, 1929, and 10 years later otoliths were systematically collected from sampled fish with the thought of using them as age determinants. Fitch found that more than 98 percent of all Pacific mackerel otoliths were readable and the oldest fish for which a definite age could be determined was in its twelfth year when caught.

Mackerel, when two years of age average 12 inches in length and weigh about three-quarters of a pound each. They do not double this weight until they are six years of age at which time they are 15 inches long. Over the 12 seasons covered by this report all but 13 percent of the average season's catch was contributed by fish less than four years of age. Nearly 65 percent of the fish caught were less than three years of age. Since most mackerel do not spawn until their third or fourth year, 65 percent of the fish caught during a season either would not have spawned or would have spawned only once.

TABLE 1

Number of Fish Landed by Year Class at Each Age Group From 0 Through V, 1939-40 Through 1950-51

Year class	Age group						Totals
	O	I	II	III	IV	V	
1934	---	---	---	---	---	5,340,000	---
1935	---	---	---	---	10,570,000	1,443,000	---
1936	---	---	---	35,130,000	13,551,000	970,000	---
1937	---	---	26,540,000	25,261,000	5,121,000	822,000	---
1938	---	25,200,000	69,322,000	25,661,000	5,271,000	1,082,000	126,536,000*
1939	2,960,000	20,793,000	26,454,000	12,698,000	7,133,000	1,616,000	71,654,000
1940	2,313,000	12,507,000	9,204,000	10,156,000	7,712,000	3,328,000	45,220,000
1941	398,000	29,376,000	54,106,000	33,905,000	10,312,000	2,294,000	130,391,000
1942	---	12,462,000	19,047,000	10,259,000	4,661,000	2,019,000	48,448,000
1943	836,000	16,556,000	10,327,000	11,872,000	5,087,000	429,000	45,107,000
1944	---	14,302,000	25,823,000	10,943,000	1,105,000	584,000	52,757,000
1945	556,000	9,330,000	7,980,000	756,000	688,000	72,000	19,382,000
1946	560,000	1,377,000	3,175,000	4,279,000	937,000	---	10,328,000
1947	7,181,000	63,330,000	49,255,000	15,826,000	---	---	135,592,000
1948	1,061,000	21,818,000	19,228,000	---	---	---	42,107,000
1949	136,000	3,854,000	---	---	---	---	---
1950	6,000	---	---	---	---	---	---

* No information available on the 0 age group of the 1938 year class.

Table 1 gives the number of fish of each year class ³ taken in the catch during the seasons 1939-40 through 1950-51. Mackerel hatched in 1947 contributed the greatest number of fish from a single year class. To date, in only four years, this year class has contributed over 135,000,000 fish to the fishery. Second best contributor was the 1941 year class with over 130,000,000 fish. Of the fish hatched in 1938, exclusive of the zero age group for which no information is available, 126,500,000 were caught, while the nearly 53,000,000 fish from the 1944 year class are fifth in order of rank, well behind the 1939's.

In Table 2 the numbers of fish in Table 1 have been converted into pounds. The 1941 year class, second in terms of numbers, is first in terms of pounds. The 1947 year class, which was well out in front in numbers,

³ A year class designates fish from one spawning season and is identified by the date spawned.

TABLE 2

Pounds of Fish Landed by Year Class at Each Age Group 0 Through V, 1939-40 Through 1950-51

Year class	Age group						Total
	0	I	II	III	IV	V	
1939						6,851,000	
1939					12,141,000	1,885,000	
1939				31,946,000	14,592,000	1,414,000	
1937			19,306,000	22,163,000	7,015,000	1,178,000	
1938		11,578,000	19,762,000	27,249,000	6,651,000	1,199,000	96,739,000*
1939	961,000	11,609,000	21,717,000	12,898,000	9,058,000	2,334,000	58,607,000
1940	853,000	7,564,000	7,809,000	10,743,000	10,139,000	4,809,000	41,917,000
1941	116,000	15,085,000	10,066,000	36,527,000	13,795,000	3,236,000	108,625,000
1942		7,912,000	16,208,000	11,453,000	6,225,000	2,863,000	41,661,000
1943	274,000	9,991,000	9,221,000	12,786,000	6,718,000	638,000	39,628,000
1944		7,296,000	22,530,000	13,035,000	1,481,000	852,000	45,197,000
1945	158,000	5,627,000	7,601,000	867,000	899,000	100,000	15,252,000
1946	129,000	1,015,000	2,365,000	4,070,000	1,078,000		8,657,000
1947	1,177,000	29,643,000	32,320,000	14,692,000			78,132,000
1948	248,000	8,612,000	13,591,000				22,451,000
1949	47,000	2,155,000					
1950	1,000						

* No information available on the 0 age group of the 1938 year class.

ranks only third in pounds of fish contributed. It is not likely that enough mackerel of the 1947 year class will be caught in the next two years to surpass the 96,700,000 pound contribution of the 1938 year class which ranks second in weight. Again in pounds the 1944 year class ranks fifth. The 1945's produced the lowest numbers and smallest poundage.

In addition to giving the total contributions to the mackerel catch for various year classes these tables show the general availability of a particular year class to the fishery. Most of the fish were fully available as two year olds (age group 2). Some year classes, however, contributed more fish as three's than as two's (1940, 1943, and 1946 year classes, Table 1), and the 1940's, 1943's, 1945's, and 1947's contributed greater numbers as one's than as two's or three's. Of particular interest is the fact that even though the 1947 year class outranks all others in the number of fish contributed it ranks only third in pounds of fish. This is a firm indication that Pacific mackerel are now being caught before they have a chance to attain a weight which would result in the highest tonnage yield to the fishery.

MORTALITY RATES

Mortality rates for Pacific mackerel have been determined both through the tagging program (Fry and Roedel, 1949) and the age work. From tagging it was calculated that this rate was somewhere between 74 and 78 percent per year for seasons 1940-41 through 1942-43. In the age work, mortality rate for fish two years of age and older has been calculated for two separate five-year periods. For the period 1938-42 the mortality rate was 48 percent between the second and third year, 62 percent between the third and fourth year, and 70 percent between the fourth and fifth year. This means that of 1,000,000 fish two years old only 59,000 would still be in existence three years later (Table 3). The mortality rate increased during the five-year period 1943-47 and was 55, 77,

TABLE 3
Pacific Mackerel Mortality Rates

1938-1942				1943-1947			
Age	Number of fish	Percent loss	Number lost	Age	Number of fish	Percent loss	Number lost
2	1,000,000	48	480,000	2	1,000,000	55	550,000
3	520,000	62	322,400	3	450,000	77	346,500
4	197,600	70	138,320	4	103,500	80	82,800
5	59,280			5	20,700		

and 80 percent per year for two-, three-, and four-year-old fish (Table 3). During this period only 21,000 out of a million would survive three years, slightly more than one-third as many as in the previous five-year period. These increasing mortality rates indicate that with present fishing methods, conditions and pressure it is not possible to build up a reserve stock of mature spawning mackerel to take care of future needs.

THE STORY BEHIND THE CATCH

From 1916 until the 1927-28 fishing season the total annual catch of Pacific mackerel in California was under 5,000,000 pounds, nearly all of which was utilized by the fresh fish trade. Landings increased to about 6,500,000 pounds in the 1927-28 season (Figure 1)⁴ and, when canning of Pacific mackerel commenced in 1928 the catch jumped to 39,500,000 pounds. As more canners started packing mackerel the demand increased and the catch rose to over 56,500,000 pounds during the 1929-30 fishing season (A, Figure 1). The sharp drop in landings during 1930-31 has been attributed to the combinations of a poor quality pack which would not sell and the economic depression which affected the entire United States at that time.

By 1933-34 new canning methods were being used, the quality of the pack improved, the economic situation had cleared somewhat and consumer demand became practically unlimited. The catch went from nearly 11,000,000 pounds to over 146,000,000 in just three seasons (B, Figure 1). This yield was too great to continue and though fishing intensity increased throughout the years, the catch has shown a general decline ever since.

The several peaks (C, D, E, and F, Figure 1) which have occurred during the decline are easily explained. The small rise in the 1938-39 season continued through 1940-41. In 1938-39 this could have been a normal fluctuation in the fishery; however, the continued rise in 1939-40 was mostly due to the influence of scoop boats. These small boats using improved fishing methods during that season caught more mackerel than the net boats. This was the first time that the scoop catch exceeded

⁴ The poundages presented in Figure 1 are state-wide landings while the age work was based on Los Angeles area landings only. These Los Angeles area landings comprised more than 90 percent of the total state landings during the period covered by this report, 1939-40 through 1950-51.

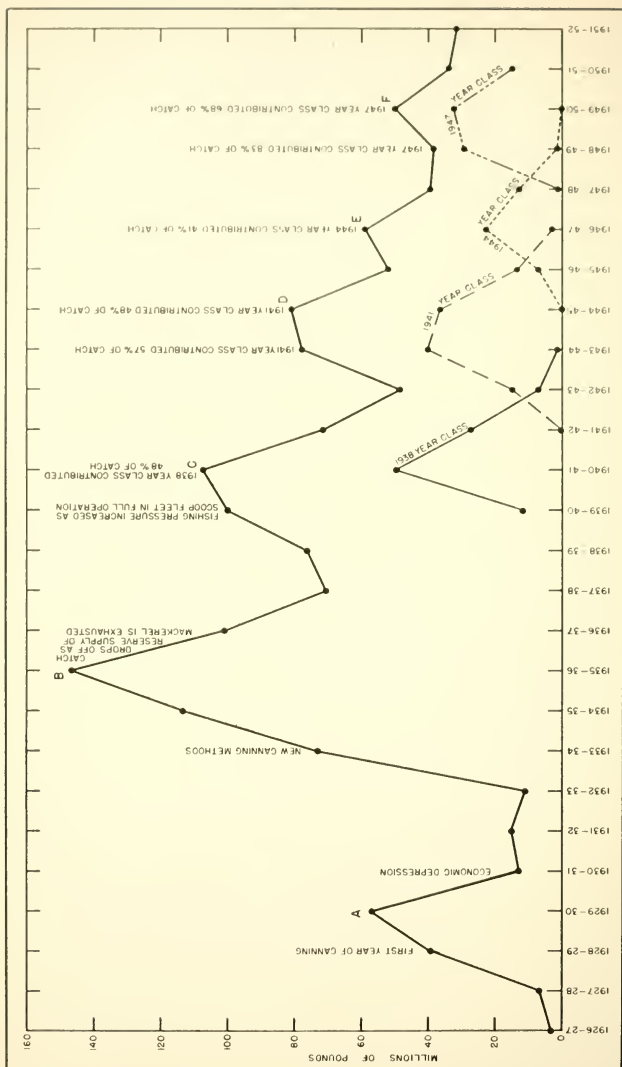


FIGURE 1. The total catch is in millions of pounds per season. Contributions of 1938, 1941, 1944 and 1947 individual year classes are also given in millions of pounds per season, for all seasons for which information is available.

the net and not until 1947-48 did net boat landings again take top place. All of the remaining increases (Points C, D, E, and F, Figure 1) can be attributed to individual year classes which resulted from extremely good hatches of eggs. The first of these was that of 1938 which at two years of age furnished over 48 percent of the total catch (1940-41 season, Figure 1). The increased catch in 1943-44 and 1944-45 was due to the dominant 1941 year class which alone contributed over 57 and 48 percent of the total catch during those two seasons.

This 1941 year class had been thoroughly exploited by 1946-47 (E, Figure 1), when again an increase in landings took place. In this season 41 percent of the catch consisted of fish from the 1944 year class. These 1944's, though of only average abundance (fifth best for seasons used in age work), comprised sufficient numbers to temporarily stay the decline in total catch and caused an otherwise average year class to assume a position of importance.

The most recent increase in landings took place during the 1949-50 season when the highly successful 1947 year class furnished over 68 percent of the total catch after having contributed nearly 83 percent of the previous season's total. During the 1951-52 season the 1947 and 1948 year classes comprised over 77 percent of the catch. Even though the 1948 year class seems to be a somewhat better than average group the total catch was less this season than in 1950-51, while the outlook for the 1952-53 season is the darkest yet.

From the knowledge obtained by age determination of the Pacific mackerel it is quite obvious that the present fishery is dependent upon incoming year classes; however, even when these young fish enter the fishery in average or better than average numbers they alone have been unable to support the entire catch and are soon destroyed. Even though recent successful year classes have individually produced more fish than some of those of former years, the trend of the catch has continued downward almost unchecked since 1935-36.

ATTEMPTS AT REGULATION

During all the years covered by this report efforts at conservation of the Pacific mackerel have been rather narrow and ineffective. Fry (1936b) attempted to warn the fishing industry that the supply of Pacific mackerel was rather limited and if fishing continued unabated it would be drastically reduced in a very short time. He compared our fishing grounds to those on the Atlantic Coast and pointed out that even though the Atlantic mackerel fishing area was three times as large as that of the Pacific, landings were not then (1936) as heavy on the Atlantic as the Pacific Coast. To quote: "The heaviest catch ever made on the Atlantic Coast—1,550 pounds per square mile—was only 58 percent of that made on the Pacific Coast in 1935. In 10 years of tremendous catches, which preceded the downfall of the Atlantic fishery, the average year's catch was 1,070 pounds per square mile.

"Since canning started here in 1928, the average annual catch has been just about the same figure, and for the past three years it has been nearly twice that—2,000 pounds per square mile—and there is every indication that fishing is going to get heavier."

The Atlantic mackerel catch had increased year by year until a peak of 233,000,000 pounds was taken in 1884, after which the fishery suffered a complete collapse. Since 1885 the catch of Atlantic mackerel has never been much over one-third of the peak year. In California the peak catch was made in the 1935-36 season when 146,000,000 pounds were taken (point B, Figure 1). This dropped to 101,000,000 pounds during the 1936-37 season and even though the fleet has increased the catch has continued to drop. In 1950 the total catch was but slightly more than 30,000,000 pounds, about one-fifth of the peak year.

According to Scofield (1938) "The whole industry, including both fishermen and cannerymen, agrees with the announcement from the California State Fisheries Laboratory that the mackerel supply has been seriously depleted by the heavy fishing." A series of conferences resulted, and the Bureau of Marine Fisheries recommended a voluntary closed season during March, April, May, and June "as the bulk of the spawning occurs during those months." After several meetings and much wrangling, the industry agreed upon voluntarily closing the season during April and May only (June was also closed during 1940 and 1941) fully realizing that only 7 percent of the total annual catch was made during these two months. Scofield (1938) remarked that "This closed season, agreed upon as an emergency measure, is, of course, inadequate to stop further depletion or bring the fishery back to a more productive basis. But it does show a spirit of cooperation and an admission on the part of the cannerymen and fishermen that mackerel need the protection of a closed season." This agreement being purely voluntary was soon ignored by the industry and after four years, 1938 to 1941, the mackerel fishery was again prosecuted on a year-round basis.

No other protection was given the Pacific mackerel until 1947, when for more than a week, purse seiners docked with 10- to 15-ton loads of 8- and 10-inch mackerel. These fish had been spawned only a few months previously and weighed less than a quarter of a pound each. All thoughts of conservation and future needs were completely ignored and the situation became so critical that the California Fish and Game Commission placed emergency minimum size limitations, effective immediately, on the mackerel. This move was supported by those progressive cannerymen and fishermen who realized all too well the damage being done. This regulation, in effect throughout the remainder of the 1947-48 season, undoubtedly kept the 1947 year class from being destroyed before it was a full year old.

FUTURE OUTLOOK FOR PACIFIC MACKEREL

The future of the Pacific mackerel in California is not a bright one. The fishery during the past 15 years has been fading rapidly. The reserve spawning stock, fish over four years old, dwindled until in 1950-51 less than 3 percent of the Pacific mackerel caught were four years of age and older. More and more is a successful fishing season dependent upon incoming year classes. Good, dominant year classes have been few and far between and even when such year classes do enter the fishery as in 1947, they alone cannot support the entire fishery. Often the abundance of these fish leads the industry to a feeling of false security. This was particularly true during the early part of the 1951-52 season; mackerel

of the 1947 year class were averaging a pound apiece and several loads of 75 to 100 tons were taken by individual boats. Many of the fishermen felt that the Pacific mackerel was coming back, that fishing was comparable to the old days.

The scoop fleet which for several years fished successfully during January and February and even into March now seldom fishes through December. With the failure of the sardine fishery and the resultant increased fishing pressure of the purse seine fleet on the Pacific mackerel there has been no substantial increase in landings.

This decline in abundance of Pacific mackerel has been masked by the increase in landings of jack mackerel and the successive entrance into the fishery of two better than average Pacific mackerel year classes (1947's and 1948's). Until the present season many in the industry were still unaware of what has happened to the Pacific mackerel fishery. The present lack of reserve stock, plus the indication that both the 1947 and 1948 year classes are nearly exhausted leads to the conclusion that the worst may be yet to come. It is entirely possible that the catch of Pacific mackerel will drop below 10,000,000 pounds within the next two seasons.

Closed seasons and minimum size restrictions might help to relieve this situation, but there is little hope that these will bring the mackerel back to their former abundance. Something must be done soon, and the California Department of Fish and Game recommends an over-all yearly bag limit. To put such a limitation into effect will require the full cooperation of the canners and the fishermen.

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ANNUAL MIGRATIONS OF CALIFORNIA STRIPED BASS¹

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A well-defined annual migration of adult striped bass (*Morone saxatilis*), initially suggested by the catch records for this fishery (Calhoun, 1949), has now been fully confirmed by a large number of tag returns.

Previous California tagging of striped bass (Clark, 1934, 1936) was limited almost entirely to small fish, mostly less than 12 inches in length and virtually all under 20 inches. The principal conclusion reached was that they made no definite migration, but simply diffused away from the tagging locality. Such behavior is apparently characteristic of immature striped bass everywhere (Vladykov and Wallace, 1938; Merriman, 1941).

It is hoped that this report will clarify the California picture by outlining the migrations of the large striped bass within the Sacramento River system and adjacent waters. These were missed by Clark because he tagged so few large fish.

The tag which has been used in our work, commonly called a Petersen disc tag, consists of a pair of plastic discs, one at each end of a wire passing through the body of the fish. Initially they were placed high on the back, beneath the dorsal fin, but later they were put in the tail region,

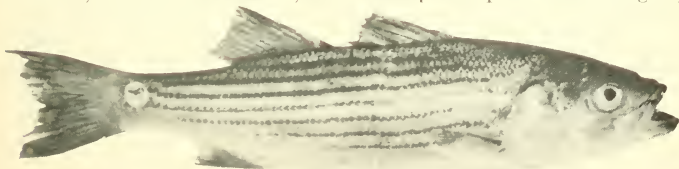


FIGURE 1. Petersen disc type of tag in place on the caudal peduncle of a striped bass

as shown in Figure 1. Many different metals and plastics have been tried since 1947, when tagging began, to discover the most satisfactory materials (Calhoun, Fry, and Hughes, 1951).

The striped bass used for this study were tagged principally during 1950 and 1951, in the spring of the year. At that season the adults are concentrated in the fresh-water Sacramento-San Joaquin Delta, and it is relatively easy to catch them in gill nets. Tagging localities were all within the hatched area shown in the first chart (Figure 5).

All fish were captured in gill nets. One method employed with great success in shallow, current-free areas like Franks Tract was to set the net in a circle, and then to create a disturbance by racing the boat around

¹ Submitted for publication February, 1952.

inside it. This caused any fish present to scatter wildly and to become entangled in the net, which was picked up immediately. The gear used for this type of operation was ordinarily about 1,200 feet long and 12 feet deep, and of large mesh size (about nine inches, stretched measurement).

Drift gill nets about 30 feet deep also proved highly effective. They were made up of four sections of different mesh sizes, from $4\frac{1}{2}$ inches to 8 $\frac{1}{2}$ inches (stretched measurement), in order to sample the various sizes of fish present. These drift nets were fished in the lower portions of the San Joaquin River, in the manner formerly employed by the commercial gill-netters, before the area was closed to them.



FIGURE 2. The *Striper*, 28-foot Fraser River type gill-netter used for striped bass tagging work

The research boat *STRIPER*, shown in the accompanying illustration, was invaluable in these tagging operations. She is a Fraser River type gill-netter, with a large, power-driven spool in the stern to handle the gill net, much as a fishing reel handles a line. Use of two tagging cradles simultaneously made it possible to handle fish as fast as the boatman could extract them from the net, with the result that several hundred could be tagged readily in a day when they were abundant. The actual tagging operation in progress is shown in Figure 3.

For the sake of convenient reference, the tagged fish have been divided into three different groups.

The first group, representing no more than pilot experiments, has been included principally because it contains the only two tags ever returned from fish caught in the Pacific Ocean proper. It consists of 336 large bass tagged at Franks Tract during January and November of 1947. Even though this represents tagging during two successive winter seasons, the returns have all been combined, since they revealed essentially similar movements, and the numbers involved were very small.



FIGURE 3. A striped bass being tagged aboard the *Striper*

Length frequencies of a representative sample of 87 of these fish are shown by the dotted line in Figure 4 (mean length 32.2 inches; standard deviation 2.04; range 25 to 37). Measurements are from the tip of the lower jaw to the fork of the tail.

The second group, consisting of about 1,800 fish, was tagged mainly during the spring of 1950. Those caught the preceding fall and winter are also included, but they are relatively few. Most of this group was caught in the San Joaquin River, in drift nets, as described previously, although some were also taken in circle nets in Franks Tract and Sherman Island Lake.

There were many more medium-sized individuals in this second group than in the first one. Length frequencies of these fish are graphed in Figure 4 (mean length 25.0 inches, standard deviation 5.07, range 12 to 42).

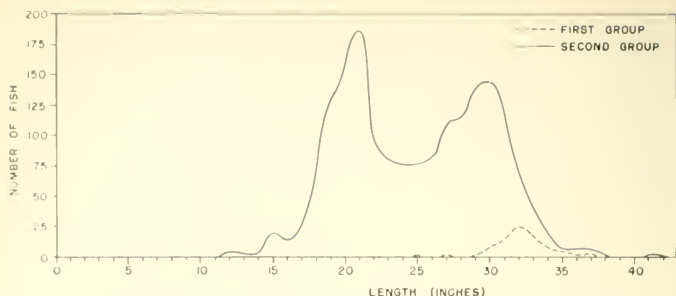


FIGURE 4. Length frequencies of tagged striped bass. The dotted line represents a sample of 87 individuals from the first group, tagged in November of 1947. The solid line represents 1,799 individuals from the second group, tagged during the 1949-1950 season.

The third and final group was generally similar to the second in all respects, except for being tagged the following season, 1950-1951. It contained about 2,000 fish.

Up to the present time (January, 1952) tag returns from these three groups for which date and place of capture are known total roughly 400. Each return is plotted as an individual mark on one of the accompanying series of six charts (Figures 5 to 10) showing where tagged fish were caught during successive calendar periods. The groups are represented by different symbols, as indicated in the legend in the first chart: group one by crosses, group two by circles, and group three by squares. The juveniles are shown by half-dark symbols in each case.

The arbitrary selection of 20 inches as a dividing line between juveniles and adults is actually an oversimplification, because the males mature sexually at a much smaller size than this. However, it is entirely satisfactory for the purpose at hand.

The first chart in the series of six shows recaptures during the winter and early spring soon after tagging. Numbers are small because fishing is always relatively poor at this season; the bass do not bite well when the water is cold. Also, fewer tagged fish were available to the fishermen than later, for large numbers were released subsequently during April and May. There is little indication of any movement away from the tagging locality during the winter, although a few individuals have traveled some distance down the river. (Figure 5.)

The second chart shows where tagged fish were recaptured during April, as spawning is approaching a peak. As yet few of the fish have had time to spawn and return to the ocean. This chart is of particular interest because it illustrates the spreading out of the striped bass into the remoter sections of the delta and its tributary rivers to spawn. (Figure 6.)

The third chart covers the brief period of six weeks in late spring and early summer when the main body of fish is moving back down to the bays after spawning. At this time they are caught simultaneously over a very wide area. (Figure 7.)

Next is the summer picture, from mid-June to the end of August. During this season virtually all recaptures of adult fish took place in the salt

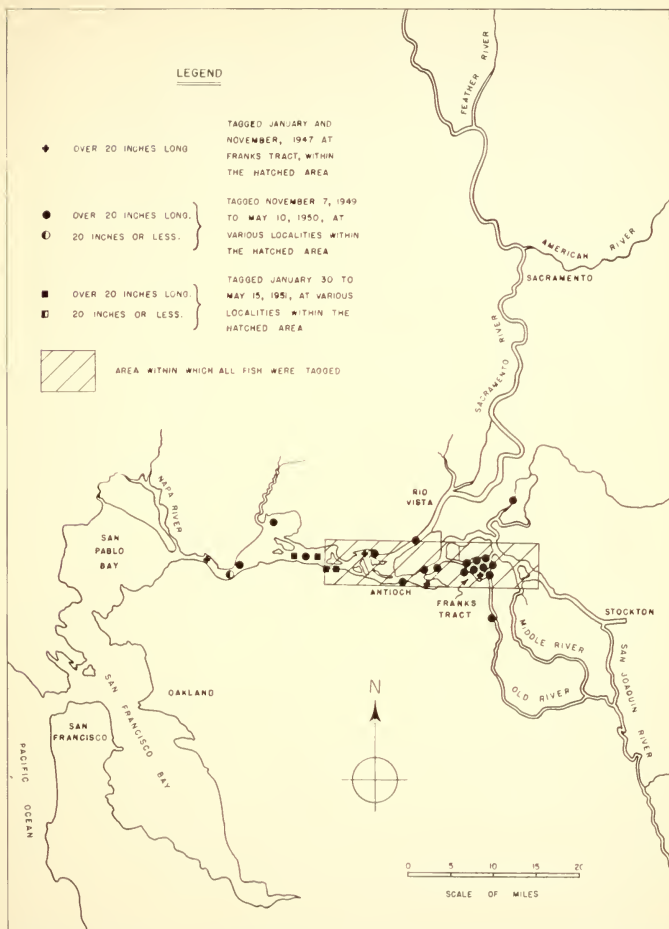


FIGURE 5. Tag recoveries from November 1st to March 31st, inclusive, immediately after tagging. During the winter the fish are concentrated in the Sacramento-San Joaquin Delta, and most recoveries were in or near the tagging area.

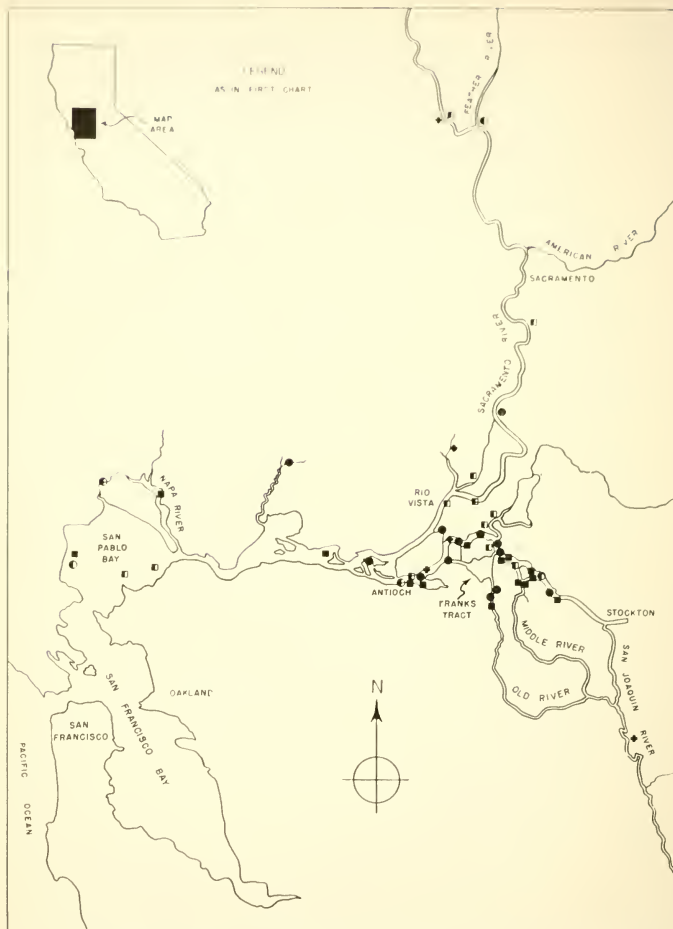


FIGURE 6. Recoveries during April. As the height of the spawning approaches, the fish spread out over the delta to spawn, and also ascend the tributary rivers.

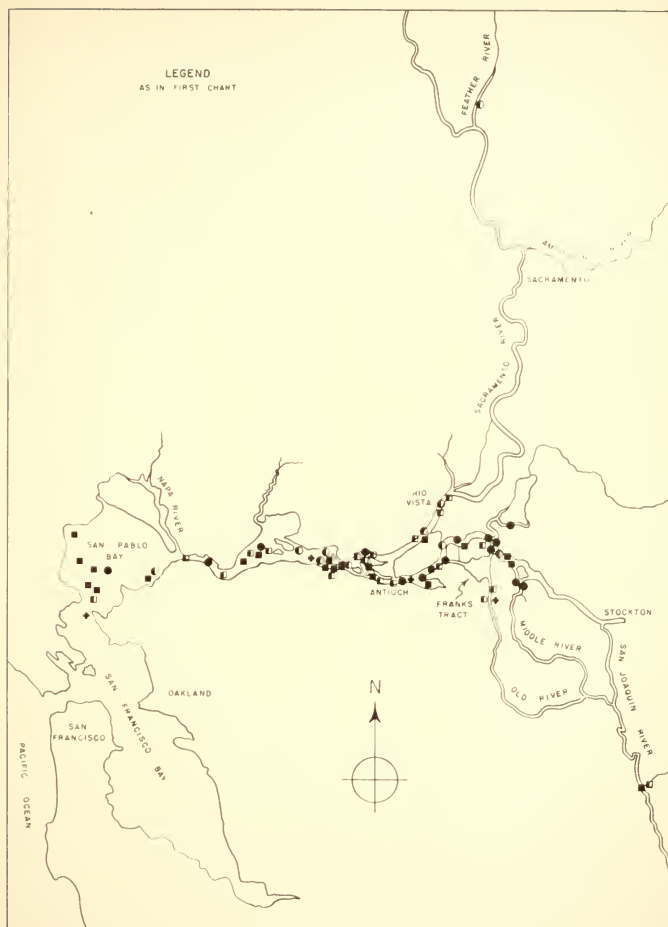


FIGURE 7. Recoveries from May 1st to June 15th.

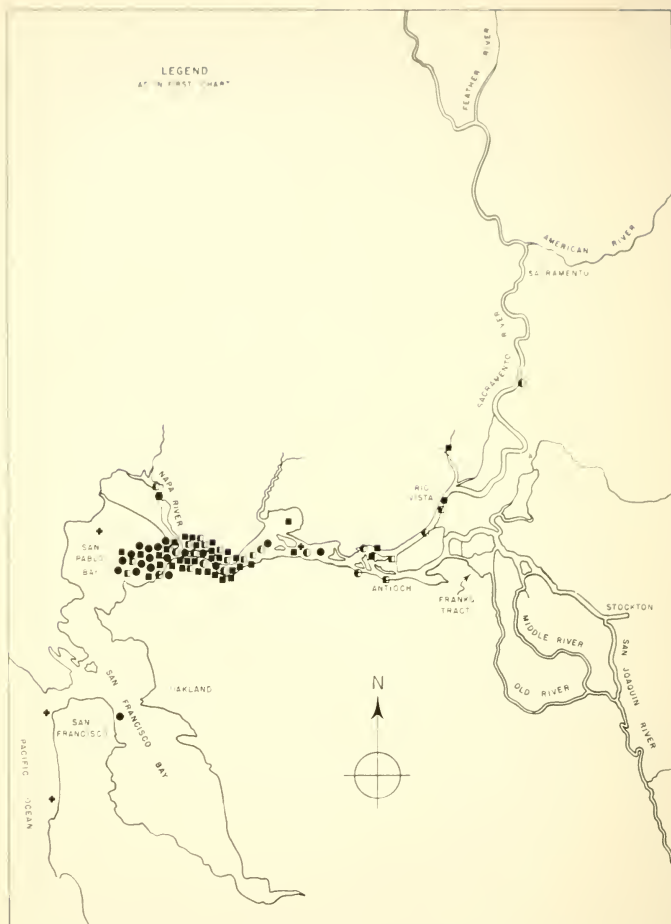


FIGURE 8. Recoveries from June 16th to the end of August. During the summer almost all the adults are in salt or brackish water.

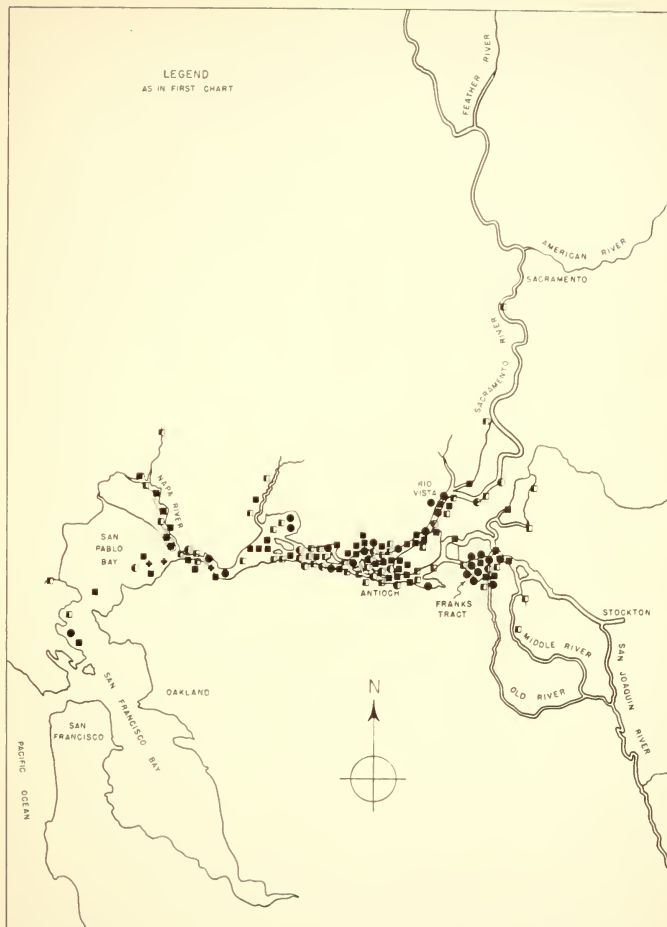


FIGURE 9. Recoveries during September and October. In the fall most of the fish pass back up into the delta again.

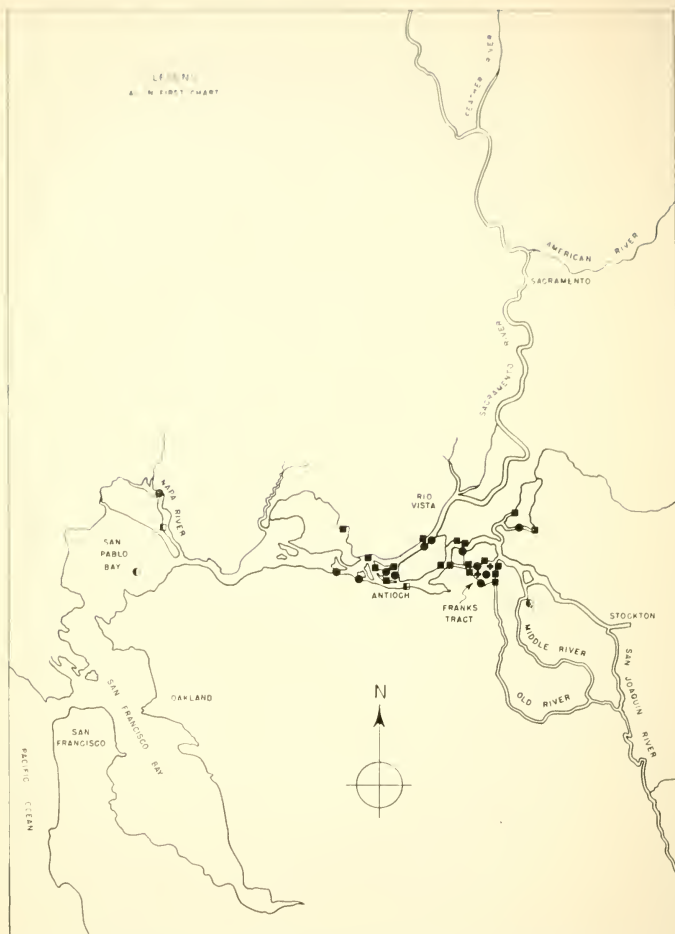


FIGURE 10. Recoveries between November 1st and March 31st, during the winter season roughly one year after tagging. This duplicates the first chart and completes the cycle.

and brackish areas inside the Golden Gate (Figure 8). Migration out into the Pacific Ocean is discussed later.

In the fall the fish again pass up into the delta, as shown in the fifth chart. These tag returns have a pattern essentially like the one in the third chart, when the bass were moving in the opposite direction, except that angling is much better in the fall and many more tagged fish were caught then. (Figure 9.)

The final chart shows recoveries during the winter season roughly a year after tagging (Figure 10). It duplicates the pattern in the first chart, and completes the cycle.

The general similarity of the distribution of the three different symbols on each of these charts attests to the regularity with which this same pattern is repeated in successive years. Four different seasons are represented simultaneously by these charts.

The few recaptures made the second year after tagging also fall into the same general pattern. They have not been shown because of the small numbers involved.

It is of interest to compare these California migrations with those which occur elsewhere. Recent striped bass tagging at Coos Bay, Oregon (Morgan and Gerlach, 1950), indicates that these northern fish behave much like those in California, having one spawning migration upstream in the spring and a second migration into the sloughs in the fall. The Oregon fish apparently migrate out of Coos Bay into the ocean in large numbers in early summer, returning again in the fall. However, as in California, they are not caught in the ocean to any extent.

In the Atlantic, the situation is apparently quite different; but this is scarcely surprising, in view of the many basic dissimilarities between the two coast lines. In Chesapeake Bay bass are said to move from the upper to the lower bay in the fall months and back in the spring (Vladykov and Wallace, 1938). This appears to be the reverse of the California cycle. A different sort of behavior, resembling that in California, is reported for the rivers of New Jersey by Pearson (1938). He also states that in Chesapeake Bay the bass spend the winter in the deeper channels of the bay and the mouths of its tributary rivers, while in southern Atlantic waters they remain more or less continually in fresh or brackish water.

A mass movement of the Atlantic striped bass north along the coast in the spring and back south in the fall over great distances has also been reported (Merriman, 1941). There is nothing to suggest that anything of this sort occurs along the Pacific Coast. Some California tags would probably have been returned from Oregon if it did. It is entirely possible, however, that more bass actually enter the Pacific Ocean through the Golden Gate each summer than either tag returns or catch records would indicate. Occasionally fishing is spectacular in the surf along the beaches south of the Golden Gate, for brief periods during the summer. This happened in 1948, the year in which the two ocean tag recoveries shown in Figure 8 occurred. However, in most years relatively few fish are taken in the ocean, probably well under 1 percent of the total. Even so, sizeable numbers could scatter along the many miles of inaccessible cliffs north and south of the Golden Gate each summer, with slight chance of being caught. It is certain that some individuals roam great distances.

The species spread from the Sacramento River north into Oregon within 20 years of the original introductions, in 1879 and 1882. The small number initially planted and the lack of intervening estuaries makes this a more remarkable feat than it might at first appear. Moreover, as early as 1906, bass were being caught in traps at the mouth of the Columbia River, some 600 miles north of the Golden Gate (Smith, 1910). Small numbers are still present there (Oreg. Fish Comm., 1948) although the species has never become abundant that far north on this coast. Occasional stragglers are also picked up hundreds of miles south of the Golden Gate, off Southern California. A 10-inch specimen was caught in a purse seine off Huntington Beach, south of Los Angeles, on May 10, 1948, and an eight-pound fish was taken from the Mission Bay Bridge near San Diego on May 27, 1947 (Fitch, 1949).

The failure of striped bass to become abundant on the Pacific Coast anywhere except around San Francisco and Coos Bay is readily understandable. These are the only two river systems south of the Columbia with extensive tidal estuaries of the sort the species seems to require for nursery areas and wintering grounds. Temperatures approaching 60 degrees F. are believed to be necessary for spawning (Calhoun, 1950), and this helps to explain why bass have not thrived north of Coos Bay. For example, in 1948 the Columbia River at Bonneville Dam did not reach this temperature until July 19 (U. S. Army Corps of Engineers, 1949), long after spawning is over in California. South of San Francisco, the limited rainfall precludes the possibility of spawning areas or nursery grounds of any consequence. Between San Francisco and Coos Bay the coast is precipitous, for the most part, and the rivers lack estuaries. Where borderline conditions exist, as in the Russian and Salinas rivers, small populations occur.

ACKNOWLEDGMENTS

This is a welcome opportunity to thank the San Francisco Striped Bass Club for its splendid publicity program in conjunction with these tagging experiments. Over a three-year period the club has awarded a great many impressive cash and merchandise prizes to anglers returning tags, at drawings held three times a year. A highly effective newspaper publicity campaign was also carried on by the club in conjunction with the drawings. Bernard Wilson, Ralph Krona, Marion Richards, George Savey, and Charles Burkhardt were particularly active in this program, and others too numerous to mention gave assistance along the way. So much interest and cooperation has been stirred up throughout Central California that it seems fairly certain that nearly all tags are being returned. This is, of course, particularly important in connection with the program's primary objective of evaluating fishing pressure.

The cooperation of the fishermen who returned tags is gratefully acknowledged. We are also indebted to Howard McCully, of the Bureau of Marine Fisheries, for suggesting and designing the plastic commendation cards sent to all individuals returning tags.

A number of California Department of Fish and Game employees assisted in this program. Vincent Catania, William Johnson, David Pelgen, and Richard Beland all helped with the capture and tagging of the fish. Jean Glass gave invaluable assistance with records and correspondence. The six migration charts were drawn by William Rowley.

SUMMARY

During the fall there is a mass movement of striped bass up into the fresh-water Sacramento-San Joaquin Delta, where they remain during the winter. In the spring they disperse out over the delta and into its tributary rivers to spawn, after which they return again to San Francisco Bay and adjacent salt and brackish waters for the summer. This same pattern was shown by returns from fish tagged during four seasons.

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A NEW MECHANICAL FISH SCREEN FOR HATCHERY PONDS¹

By EARL LEITRITZ
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California Department of Fish and Game

Continued experimentation by employees of the California Department of Fish and Game in the development and manufacture of mechanical fish screens has resulted in the design of a unique rotary-type screen by Mr. William Richardson, Fish Hatchery Foreman.

The necessity for a screen of this type became apparent at our newly-developed Fish Springs Hatchery, near Big Pine, Inyo County, where because of considerable fluctuation in water levels it was necessary to install pond dams having an over-all height of eight feet. In addition, the gradient at the pond site did not permit a fall between ponds greater than five inches. For satisfactory operation it was therefore necessary to design a screen which would be self-contained, as light as possible (to provide for ease in adjusting to varied water levels), and operable with a minimum of fall between ponds.

The screen designed by Mr. Richardson meets these requirements. Its metal paddle boards are enclosed in a cylinder, so that there is no danger of fish being injured by the paddles, and the screen can easily be adjusted to fluctuating water levels by raising or lowering it in the pond dams. It is an easy matter to make it fish tight by sealing around the framework holding the screen.

The mechanics of this screen are quite simple. The cylinder revolves on a fixed shaft to which is fastened a flat piece of metal which projects downward in a vertical position to within a very short distance of the screen circumference. The enclosed paddles are slightly longer than the radius of the cylinder and are hinged to the cylinder. Instead of being straight, the paddles are curved to fit the contour of the screen cylinder. They are forced by the current to swing up after passing the center line of the screen and lie close to the screen cylinder. This permits the paddles to pass under the fixed vertical plate. After passing under this piece of metal, the paddles are again caused by the current to swing up to the extent that the lower edge of the paddle is forced against the center shaft. This causes the paddle to become momentarily rigid, offering resistance to the current and causing the screen cylinder to rotate.

This screen is a new development and, although it has been tested for only a relatively short time, appears to have great promise for use at hatchery ponds. Its simplicity in design, which avoids the use of gears, cams, or ratchets, and few moving parts are very desirable features.

In Figure 1 the paddles are numbered. Paddle No. 1 is lying against the screen circumference and is in position to pass under the fixed piece

¹ Submitted for publication January, 1952.

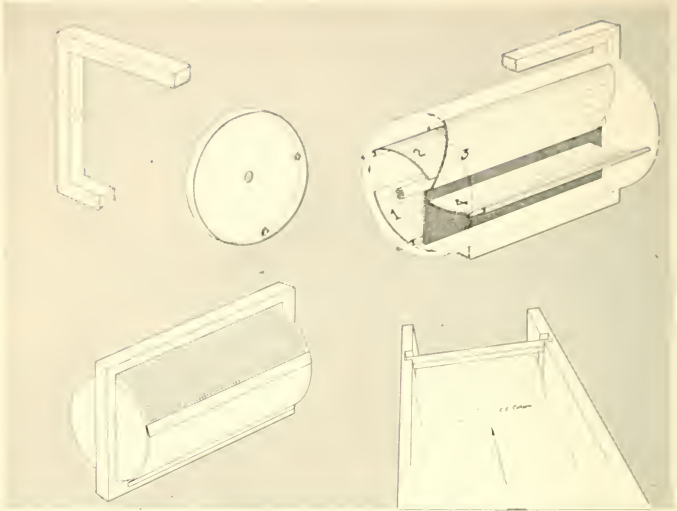


FIGURE 1. Richardson fish screen. Drawing by Clifton E. Corson.

of metal fastened to the shaft. Paddle No. 2 has already passed the center of the screen and is being forced by the current toward the screen circumference. Paddle No. 3 is in drive position, causing the cylinder to rotate. Paddle No. 4 has passed under the fixed piece of metal and is moving into drive position.

INTRODUCTION OF SUCKERS INTO THE UPPER SAN JOAQUIN RIVER DRAINAGE, CALIFORNIA¹

By RALPH V. BECK
Bureau of Fish Conservation
California Department of Fish and Game

Starkweather Lake is a small lake in Madera County, situated at an elevation of 8,000 feet, less than one-half mile east of the Middle Fork of the San Joaquin River near the Devil Postpile National Monument. Although it lies on the western slope of the Sierra Nevada, access is by road from the Mammoth Lakes area on the eastern slope. It occupies a small basin in rock, sand, and pumice soil and is surrounded by timber, chiefly lodgepole pine. The lake has no permanent inlet or outlet and apparently spills into the river only during high water periods, such as the spring run-off. Like most waters in the upper San Joaquin drainage, it was originally barren of fish life, but has provided a small trout fishery for some years through artificial stocking.

In June, 1951, the presence of suckers in Starkweather Lake was reported by Mr. Arch Mahan, packer in that area. Subsequent investigation confirmed this report and indicated a moderately heavy population of *Catostomus* sp. Although a positive identification was not made, the fish were probably *C. tahoensis*, a Lahontan species. How or when these fish were introduced is not known; it is probable that they were brought in illegally by bait fishermen. Kinsey (1950) has recorded a similar introduction of east slope fishes into a west slope Sierra Nevada drainage.

In order to safeguard the lake's fishery, and especially to prevent the introduction of suckers into the river below, the Department of Fish and Game took immediate steps to eradicate them. On July 10, 1951, the three and one-half acre lake was treated with 165 pounds of cube powder with a rotenone content of 4.8 percent, which gave a concentration of 0.058 p.p.m. rotenone to water. An additional 15 pounds were used in the treatment of two small ponds below the main lake.

Fish began to appear at the surface about one hour after the start of treatment. Approximately 50 rainbow trout (*Salmo gairdneri* Richardson) were recovered at the time of treatment, and possibly five times this number were not recovered. An undetermined number of suckers was killed. Although the population did not appear large for the size of the lake, possibly 10 or 20 times as many suckers as trout were present. They ranged in size from fry to fish about 14 inches in length.

All indications were that a complete kill was achieved. In live car tests with fingerling rainbow trout conducted five weeks after treatment, all fish died in less than one hour after being placed in the lake, indicating that it was still highly toxic.

¹ Submitted for publication January, 1952.

It thus appears fairly certain that the sucker population in Starkweather Lake was eradicated. Suckers have not been reported from the river in this area, and the infrequent and short periods of time when there is a water connection between the lake and the river encourages the hope that none of the introduced fish had left the lake. However, the possibility exists that some had already made their way downstream.

Insofar as is known, the San Joaquin River and its tributaries have never contained suckers or any other rough fish in the 45 miles of stream above the cascades about one and one-half miles below Mammoth Pool. The presence of suckers in Starkweather Lake is recorded here, therefore, in order to prevent possible confusion in the event that they are ever discovered in the upper portion of the river by later workers.

Additional work is planned for this area because of an unconfirmed report, received late in 1951, that suckers are also present in Sotcher Lake, some three miles south of Starkweather Lake. This and other nearby waters will be investigated, and if suckers are found they will be removed.

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A GUIDE TO THE GRUNION¹

By BOYD W. WALKER

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Grunion have been known to many Southern Californians for more than 30 years, but there are still those who consider them part of a prankster's story. One can hardly be blamed for being skeptical of an invitation to go fishing at night, with only a light and a gunny sack for equipment. It smacks too much of a poor variation of the snipe hunts, to which most tenderfeet are initiated in the Boy Scouts. Stories of fish coming out of the sea to dance on the sand of moonlit beaches certainly sound like a line from the Irish, but in reality they are not far from the truth.



FIGURE 1. The grunion, *Leuresthes tenuis*

The grunion are small silvery fish found only along the coast of Southern California and northern Baja California (Figure 1). They doubtless would be unknown to most people, if it were not for their peculiar spawning habits. Unlike other fishes, the grunion come completely out of the water to lay their eggs in the moist sand of the beach. As if this behavior were not strange enough, the fish make these excursions only on particular nights, and with such regularity that, with the aid of tide tables, the time when they arrive on the beach can be forecast a year in advance. This amazing phenomenon can be seen on most beaches in Southern California. On certain nights, shortly after high tide, parts of these beaches sometimes are covered with thousands of wriggling fish depositing their eggs in the sand.

Grunion hunting has become one of the famous sports of Southern California. Since these fish leave the water to deposit their eggs, they may be picked up while they are briefly stranded. Racing for fish spotted far down the beach, and clutching for the small bits of slippery, wriggling energy provides an exhilarating time for young and old alike. The attraction provided by the grunion can only be realized when one sees the thousands of people lining the more popular beaches in the Los Angeles area on the night of a predicted run. Often there are more people than fish, but at other times everyone catches fish.

¹ Submitted for publication March, 1952.

RELATIONSHIPS

The grunion is a slender fish, with a bluish green back and bright silvery sides and belly. The average size is between five and six inches. Its scientific name is *Leuresthes tenuis*, and it belongs to family Atherinidae. Other atherines or silversides found in California are the jack smelt (*Atherinopsis californiensis*) and the top smelt (*Atherinops affinis*). These fish should not be confused with the true smelts of more northern waters, which belong to the family Osmeridae, and which, like trout, have an adipose fin. The top smelt and jack smelt are more abundant than the grunion and are important market fish in California.

DISTRIBUTION

The principle range of the grunion is between Point Conception in Southern California and Punta Abreojos in Baja California. There are small populations both north and south of these points, however. Occasionally grunion appear in fair numbers as far north as Morro Bay, California, and strays have been reported from as far north as Monterey Bay, California. A closely related form (*Hubbsiella sardina*), with much the same habits, lives in the northern part of the Gulf of California.

THE LIFE HISTORY

Spawning

The spawning season extends from late February or early March to August or early September, varying slightly in length from year to year. The actual spawning is restricted to a relatively few hours during this period. The grunion spawn only on three or four nights following each full or new moon, and then only for a one- to three-hour period immediately after high tide.

The spawning run is heralded by a few lone fish (usually males) which swim in with a wave and an occasional one is left on the beach after the wave retreats. Gradually more and more fish come in with the waves, and, by swimming against the outflowing water, strand themselves on the beach until another wave washes over them. Spawning usually starts about 20 minutes after the first fish come in. The peak of activity is reached about an hour after the start of the run and lasts for one-half to one hour. During a good run, thousands of fish may be on the beach at one time, literally turning it to a sheet of shimmering silver (Figures 2 and 3). Typically the run lasts one to three hours, but the number of fish on the beach at any instant varies from none to multitudes. Finally when the tide has dropped a foot or more, the run slackens and then stops as suddenly as it started. No more fish will be seen that night, and they will not appear again until the next night or the next series of runs.

The spawning behavior is extremely interesting and easy to observe, but many grunion hunters never see it because they are too eager to catch the fish. Actually observing the fish can be much more interesting than catching them.

The female swims onto the beach accompanied by one or more males. As many as eight males have been observed mating, or attempting to mate, with one female. If no males are present the female will return to



FIGURE 2. Grunion covering the beach at Venice. Photograph by Joseph Brauner, May, 1950.

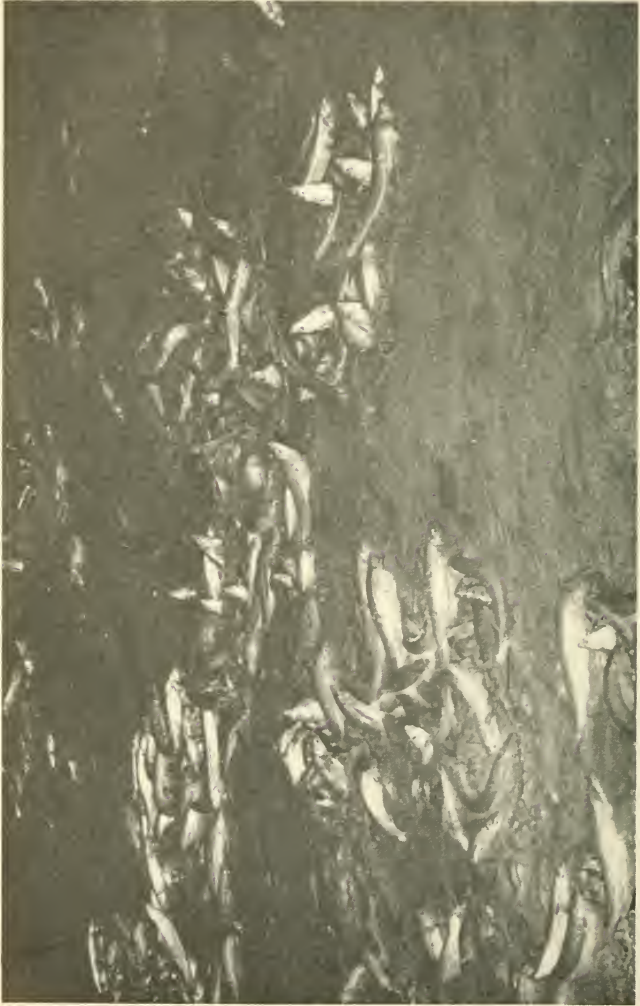


FIGURE 3. There are over 30 spawning females in this small section of beach. Photograph by Joseph Brauner, May, 1950.

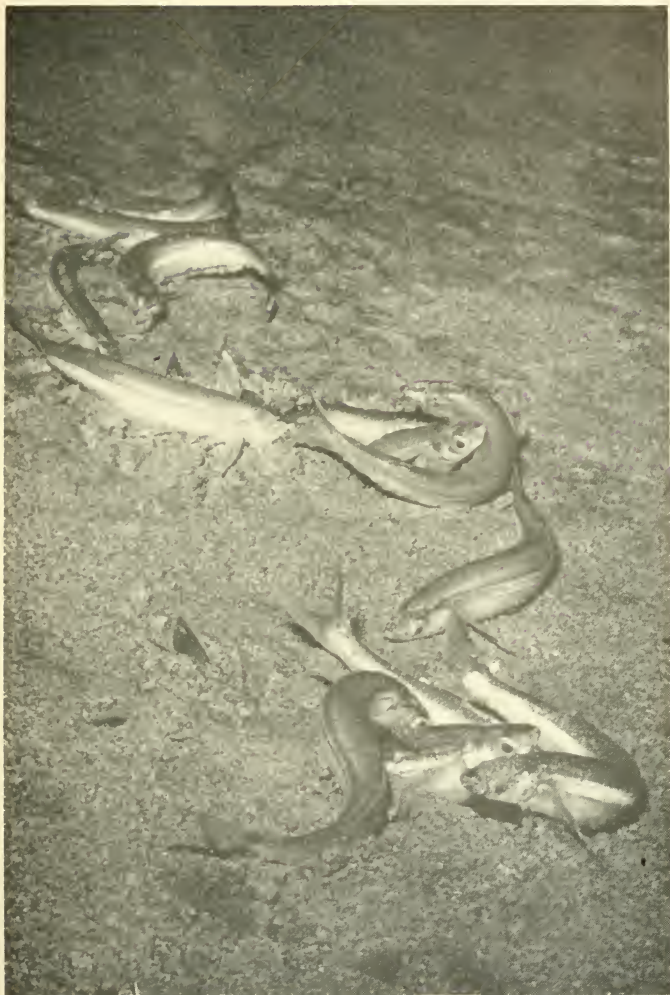


FIGURE 4. Two female grunion, surrounded by males, start to dig into the sand.
Photograph by Joseph Brauner, May, 1950.



FIGURE 5. The female grunion, here surrounded by four males, laying her eggs in the sand. Photograph by Joseph Brauner May 1950.

the ocean with the outflowing wave, but in their presence she swims as far up on the sand as possible, and digs herself in as the wave recedes. This is accomplished by arching the body with the head up, and at the same time vigorously wriggling the tail back and forth. As her tail sinks into the semifluid sand, the female twists her body and literally drills herself downward until she is buried up to the pectoral fins (Figures 4 and 5). Occasionally she may bury herself completely. The male, or males, curve around her as they lie horizontally on top of the sand, with their vents close to or touching her body. The female, continuing her twisting, emits her eggs two or three inches beneath the surface of the sand. The males discharge their milt onto the sand near the female, and then immediately start to wriggle towards the water. The milt flows down about the body of the female, and fertilization of the eggs results. The spent and obviously tired female then frees herself from the sand and returns to the sea with the next wave to reach her. The actual process of digging in and egg laying takes about 30 seconds, but individual fish may stay on the beach for several minutes.

The females spawn about four to eight times during the season, on consecutive runs. The number of eggs varies with the size of the fish: large females produce about 3,000 eggs every two weeks, small fish produce about 1,000. During the early part of the season only the older females spawn, but gradually the fish born the previous year come into breeding condition, and during April and May fish of all ages spawn. After this time the number of spawning fish diminishes.

The Fate of the Eggs

The eggs, deposited about two inches below the surface of the beach by the female grunion, are buried deeper by sand deposited by the outgoing tide. The succeeding lower tides leave the eggs covered by 8 to 16 inches of sand. Here they remain, out of water, but in the moist sand, for about 10 days, at which time the next series of high tides erodes the beach and washes them out of the sand. Two or three minutes after the eggs are freed from the sand the baby grunion hatch and are washed out to sea.

Adaptations

The habits and timing of the grunion are adapted to the tidal cycles in a wonderfully precise manner. The heights of the tides vary according to the position of the moon, the highest tides occurring when the moon is full or new. Also, along the Pacific Coast, the two high tides of each day vary in height. During the spring and summer months the higher tides are at night. The grunion spawn only on these higher tides, and after the tide has started to recede (Figure 6). Since the waves tend to erode sand from the beach as the tide rises and deposit sand as the tide falls, it is plain that if the grunion spawned on a rising tide the eggs would be washed out by succeeding waves. This danger is averted by the fact that spawning is usually confined to the falling tide. Furthermore, the grunion almost always spawn on a descending tide series when succeeding tides are lower than those of the previous night. The eggs would be washed out by succeeding tides if spawned on the ascending series. The spawning must take place soon after the highest tides, however, if the eggs are to have sufficient time to develop before the next series of high tides washes

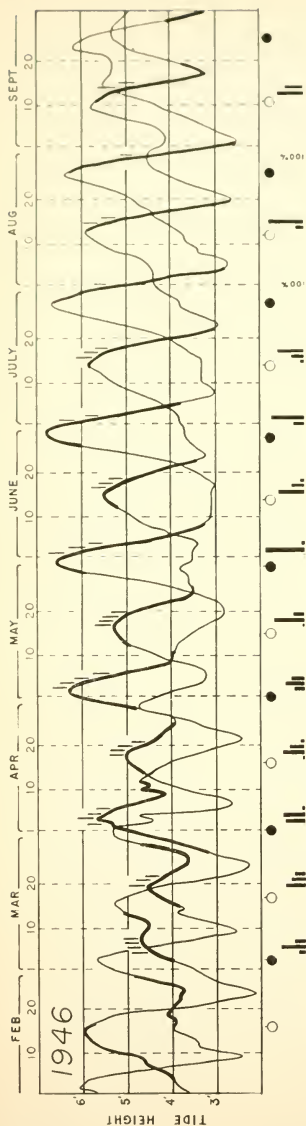
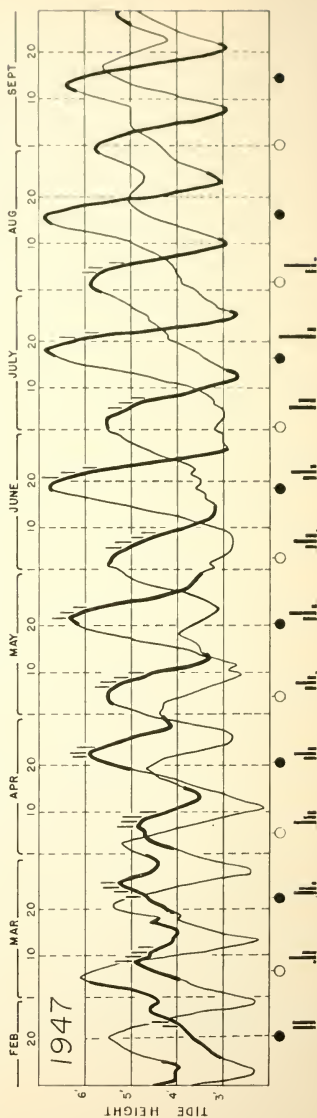


FIGURE 6. Grunion runs observed at La Jolla, California, in 1946 and 1947, plotted in relation to variations in observed high tide heights at La Jolla. The heights of high tides only have been plotted. The high tides about 24 hours apart have been connected by smooth lines. The two tides of each day yield the two series of curves. Tides occurring during darkness are indicated by the heavier lines. The occurrence of grunion runs is indicated by the short vertical lines above the tide curves. The mean phases are indicated at the bottom of each graph, by a solid circle to indicate new moon and a hollow circle to indicate full moon. The histograms at the bottom portray the percentage intensity of runs in each series of runs. Seasonal variation in strength of runs is not indicated. All data are based on observations made at Scripps Beach, La Jolla. Data for time and height of tides are from records of the tide-recording machine maintained for the Coast and Geodetic Survey on Scripps Pier.



them free. From the foregoing, we can see that there are only three or four nights available when conditions are right for spawning, and it is these which the grunion utilize. Just how this timing is controlled is not known.

The hatching of the eggs also shows remarkable adaptations to the environment. They will not hatch until they are uncovered and agitated by the surf, but they do hatch within a few minutes after this stimulus. Thus they cannot hatch prematurely in the sand, where the young fish cannot survive, and they hatch rapidly in the surf and so reduce the time they must spend in this rough and dangerous area. If the eggs fail to be washed free they can remain in the sand for another two weeks, and will still hatch if washed free by the series of high tides following.

Age and Growth

The baby fish grow rapidly and are about five inches long by the time they are one year old and ready to spawn. The normal length of life for a grunion is two or three years, and an occasional individual lives four years. Growth is much slower after the first spawning. Growth stops during each spawning period, so the fish increases in size only during fall and winter. This cessation of growth during spawning causes a mark to form on each scale, and by counting these marks, the age of the fish can be determined. The maximum size is between six and seven inches.

Most of the grunion's life is spent within a few miles of the shore line, in water 15 to 40 feet deep. This phase of the life history is not well known, but apparently they never stray far from the beach areas on which they spawn.

OTHER FISHES HAVING SIMILAR SPAWNING HABITS

Mention has already been made of a closely related species, *Hubbsiella sardina*, which occurs in the upper part of the Gulf of California. The spawning habits of this fish are almost identical to those of the grunion, except that *Hubbsiella* often spawns during daylight hours. Observations made by the author and reports from fishermen indicate that this fish runs on the same dates as do the grunion of California. They run at about the same time relative to high tide, though the times of high tides vary markedly between these two areas. Since paved roads have attracted many people to the upper part of the Gulf of California, the daylight runs of *Hubbsiella* have been often observed. The night runs are rarely observed since they usually take place during the early morning hours. It is probable, however, that the night runs occur with more regularity than do the daylight runs. *Hubbsiella* starts spawning earlier in the season than *Leuresthes*. The author observed good runs at night at Guaymas, Sonora, Mexico, in January, 1950. There were no daylight runs during this period.

The surf smelt (*Hypomesus pretiosus*), a member of the true smelt family which ranges northward from California, comes to the beaches to spawn but does not actually leave the water to lay its eggs. The eggs are broadcast in the very shallow water of the wave wash. There is no well-marked rhythm to the spawnings (Thompson, 1936).

A fish in Australia, *Galaxias attenuatus*, most closely approaches the grunion in its adjustment of spawning times to the moon phases although it does not spawn on the beach. It seems to show about the same rhythm

and regularity as does the grunion, even though its spawning habits are quite different (Hefford, 1931a, 1931b).

TIPS TO GRUNION HUNTERS

There are so many people watching for grunion these days, and such a high percentage who are disappointed, that a few pointers in the art of grunion watching are in order.

Regulations

A state fishing license is required to capture grunion. The season for capture is closed during April and May (this is a good time for observation). No nets or implements of any sort may be used to catch grunion. Pick them up with your hands.

When to Go

Predictions of dates and times for grunion runs are made each year by the Bureau of Marine Fisheries, California Department of Fish and Game. These are published in most Southern California papers, and are also available in the abstract tide tables given away by many sporting goods dealers. If these predictions are not available, the grunion hunter may make his own predictions by a few simple rules. Runs are most apt to occur on the second, third and fourth nights after each new or full moon from March through August. Thus if the full or new moon is on the second day of the month, the runs would be predicted for the fourth, fifth and sixth. To determine what time of night the runs are apt to come, tide tables are needed. Look up the time for the night high tide, and then figure that the grunion will be expected at that time or about one-half hour later, and that the run will last for two or three hours.

There is some variation in the timing of grunion runs from year to year, and during each year the pattern changes somewhat. These variations are not great, but are large enough to make it impossible to predict all runs with absolute accuracy. The above rule will produce correct predictions at least 75 percent of the time, however. Many people think the best runs should be on the first night of each series of runs, just as on the first day of hunting season. The middle day of the predicted series is the one most apt to be accurate, however, and, if the grunion are running right on schedule, the time of the heaviest run. Remember also the heaviest part of the run on any particular night usually occurs at least an hour after the start of the run. I have often seen very heavy grunion runs after most grunion hunters had quit because there were few fish 45 minutes after high tide time.

The best runs occur during April, May and June. During April and May activities must be limited to looking because these months are closed for the capture of grunion. There are usually good runs in March and July also, but the August runs are much lighter. North of Point Conception the runs start later in the year, and best runs there are in July and August.

Where to Go

The grunion run on most beaches in Southern California, but they do not run on all parts of these beaches. Local topography causes the grunion to concentrate in certain areas which are difficult or impossible to determine except by experience. Often the runs will be concentrated on one short stretch of a beach several miles long. These spots may vary from year to year, so it is best to walk the beach when looking for grunion. The ends of beaches are often the best spots. Some of the areas in California where good runs take place are, from north to south: beach between Morro Bay and Cayucos, Pismo Beach, Santa Barbara, Malibu, Santa Monica, Venice, Hermosa Beach, Cabrillo Beach, Long Beach, Belmont, Huntington Beach, Newport Beach, Corona del Mar, Doheny Beach, Del Mar, La Jolla, Mission Beach, Coronado Strand. Many beaches in Baja California are the sites of good runs, and there are fewer hunters there with whom to compete. San Miguel and the beaches southwest of Ensenada are particularly good. Good runs are more apt to take place on uncrowded beaches.

Suggestions as to Gear

Nothing special is required except the willingness to get your feet wet, and a container to carry your fish. It is advisable to wear old clothes, because most people get wet, even though the grunion do come out on the beach. Remember that the waves come in fast sometimes, and few people can outrace them every time. Many grunioners prefer bathing suits, but a jacket is desirable on most nights. Flashlights are useful, and I think are desirable equipment. Many old-timers frown on their use, because they scare the fish when misused. Lanterns cannot be properly controlled, and are not recommended. A small gunny sack makes a good grunion creel.

What to Do When You Get There

Grunion can best be found by walking up and down the beach, just above the wash of the waves. Watch the area of wave wash, for this is where the grunion will be found. A flashlight is useful to light the beach, but it should be used only when the waves have receded. If flashed on the water it tends to scare the fish, and they will not stay on the beach. During a heavy run nothing seems to deter the fish, but during light runs, lights may keep the fish away from the hunter. Splashing in the water also tends to scare the fish, so if the fish are few it is best to move only between waves. The fish are practically impossible to catch in the water. When fish are sighted, move to the area where they are seen, but if they do not appear again soon, look for better areas.

Hints on Cooking

Grunion should be cleaned and scaled. They then may be broiled or fried. Deep frying seems to produce the best results. The grunion should be rolled in a mixture of flour and yellow corn meal to which a little salt has been added, then dropped in a pan of hot cooking oil. The oil should be deep enough to cover the fish, and hot enough to brown a crumb of bread in about 30 seconds. Let the fish cook until golden brown, then remove and drain.

CONSERVATION

Despite local concentrations, the grunion is not an abundant fish and apparently never was common enough to support a commercial fishery. Definite signs of depletion were evident as early as 1926, and in that year a closed season was enacted, protecting them during the months of April, May, and June. This legal protection, plus the efforts made to overcome pollution in Southern California waters, appears to have been successful, and good runs again appeared. In 1948, the population was judged large enough to allow a longer open season, so June was added to the list of open months. There are no signs that the additional open month is causing undue depletion, and it is probable that the grunion population can maintain itself at a high level under this rule.

A marking experiment made by the author in 1948, 1949 and 1950, indicates that there is relatively little movement of grunion populations on our coast. In the future, if depletion should occur in certain areas, then local controls would probably be sufficient to remedy the situation.

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SOME DISEASES AND PARASITES OF AMERICAN COOTS¹

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In connection with various phases of a study of the breeding behavior of the American coot, *Fulica americana* (see Gullion, 1952, and earlier papers), a considerable number of wild-trapped coots were procured from the Gray Lodge Game Refuge in Butte County, California, during the winter of 1949-50. Of 48 freshly trapped coots from this source examined for disease and parasites, 42 birds (88 percent) proved to be infected. Most of the infestation was by helminth parasites, which will be reported elsewhere by Harry Wessenberg. However, certain other infestations were found which are here described.

ASPERGILLOSIS

Fungal infections occurred in the respiratory tracts of three birds. Two were minor in extent but the third coot had its left posterior thoracic air sac almost completely filled with a mold. Samples of this mold were submitted to Dr. Kenneth B. Raper, Agricultural Research Administration, U. S. Department of Agriculture, Peoria, Illinois, for identification. Dr. Raper identified the mold as a strain of *Aspergillus flavus* Link. He states (in correspondence), "There are numerous reports of this species having been isolated from sources where possible implication in disease conditions is indicated. It is not, however, common to find it in the air sacs of birds. The species usually isolated from air sacs and respiratory tracts of birds is *Aspergillus fumigatus* Fres."

ARTHROPODA

While no systematic search was made for Mallophaga, they were noticed on a few occasions. Generally speaking, the coots handled in this study did not seem to be heavily infested with biting lice.

A tick, *Haemaphysalis leporis-palustris*, identified by G. H. Rohrbacker, Jr., Division of Entomology and Parasitology, University of California College of Agriculture, Berkeley, was found on the head of one coot. This organism has been widely reported from other species of birds and mammals.

Small whitish mites were found among the cartilaginous nasal processes of the ethmoid bone in three coots. From 6 to about 20 mites were found in each bird. Dr. D. P. Furman, Division of Entomology and Parasitology, University of California College of Agriculture, Berkeley, has recently informed me that these mites apparently constitute an undescribed species

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of the genus *Spelcognathus*. A similar species, *S. sterni*, has been described from starlings (*Sturnus vulgaris*) in the eastern United States.

PATHOLOGY

In only two instances were serious cases of parasitism encountered. The one coot with the extensive aspergillosis might well have succumbed to the infection. Another coot died in captivity and upon examination it was found that nearly 70 percent of the gizzard lining contained the haemorrhagic burrows of the roundworm *Amidostomum railleti*, identified by Harry Wessenberg, Department of Zoology, University of California, Berkeley. This bird's digestive tract was free of food material. Whether the extensive parasitism was the cause of death could not be determined.

OTHER PUBLISHED REPORTS OF COOT DISEASES AND PARASITES

During weeks immediately preceding the start of this study in 1949, a severe epidemic of fowl cholera swept the San Francisco Bay area. Reporting on this epidemic, Rosen and Biscoff (1949, p. 187) state, "Apparently the mudhen is more susceptible than any other waterfowl." They say further (p. 188), "these birds made up from 70 to 100 percent of the mortality." Since they indict gulls (*Larus* sp.) as contributing to the rapid and widespread transmission of this disease, the habit of coots feeding upon gull feces might contribute materially to the high incidence of cholera among coots as well as to a speed-up of the infection in local duck flocks.

Several authors have reported previously upon the parasites of coots. Roudabush (1942) working on fall migrating coots in Iowa reported four species of Protozoa, three species of Trematoda, two species of Cestoda, one Nematoda and six species of Mallophaga. Sooter (1937; 1941, p. 68) records young coots dying from infestations of a leech, *Thermonyzon occidentalis*. He further reports (1941, p. 69) a very high incidence of helminth parasitism among young and immature coots in Iowa. Rauseh (1947) reported pullorum disease in a coot taken in Ohio. Trautman, et al. (1939, p. 95), reported severe enteritis in two and abdominal abscesses in another of 20 weather-killed coots along Lake Erie. Kalmbach (1934, p. 38) reported that though coots died from botulism "the number succumbing was proportionately small compared with the total number of coots present." Additional notes on helminth parasites of coots have been recorded by Ransom (1909), Cram (1927), and McNeil (1948).

Jones (1940, p. 11) reported lead shot (and hence possible lead poisoning) in only 12 of 792 coot stomachs examined by him. He remarks that this "is in direct contrast to its high frequency among ducks and other waterfowl" and concluded, "it is doubtful whether poisoning from ingested lead is a serious menace to them."

SUMMARY

Parasitism in the coots handled in this study did not appear to be of pathological proportions. However, the high incidence of occurrence of a variety of parasitic organisms indicates that any lowering of the birds' vitality might quickly result in severe pathology. This is believed to have been true in one instance.

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CLEANING LOSSES IN KING AND SILVER SALMON¹

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The State of California imposes a tax of one-half cent per pound on all commercial salmon. Most of this fish is landed dressed, head on, but the Fish and Game Code (Section 1015) specifically states that the tax is based on the weight of the salmon in the round. In calculating this tax, it has long been the custom of the Department of Fish and Game to estimate the round weight by adding 10 percent to the dressed weight. Some of the taxpayers affected have protested that the 10 percent is much too high. As a result of such protests, the writer was asked to examine available data and determine just how great the loss actually is.

The data in question had been gathered from time to time while doing other work. The data is not sufficient for a truly elaborate study of the factors affecting cleaning losses, but it is more than adequate for the purpose at hand.

The ratio of round weight to weight dressed, head on, was obtained for 227 king salmon and 83 silver salmon (*Oncorhynchus tshawytscha*, *O. kisutch*). The loss for each of nine samples is shown in Table 1. Note that the average loss for king salmon is 12.8 percent, and that no sample showed a loss below 12.2 percent. Samples number 2 and 3 contained some very small fish (well below legal size). They were fish which were killed by fish and game men who were catching salmon for tagging. It might be argued that such small fish should not be included. If these two samples are removed, the average loss becomes 12.4 percent.

Sample number 7 (the counterpart of sample number 2) contained some small silver salmon taken by the tagging crew. Sample number 8 contained fish which were gorged with food. Actually gorged and hungry fish should both be included in an average, but even if both sample 7 and sample 8 are removed, the average cleaning loss is 13.9 percent.

The variation in cleaning loss of king salmon with size of fish is shown in Table 2. Data from samples number 1, 4, 5, and 6 were included in this table since each of these samples included a wide range of sizes. Data on these samples is given in Table 1.

There appears to be a slightly greater loss in the largest fish. This was due at least in part to the growth of the sex organs. No size group shows a weight loss less than 12.2 percent.

The same calculations were not prepared with silver salmon because almost all of these fish were in "under 10 lbs." class.

Differences in weight losses of males and females were calculated. King salmon females showed a 1 percent greater weight loss than males, and silver salmon females showed an 0.7 percent greater loss than males.

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From the above figures, it would appear that the department's calculation of salmon cleaning loss is generous to the taxpayer. The department adds 10 percent to the dressed weight; no one would have any right to complain if this figure were raised to 12 percent.

TABLE 1
Cleaning Loss Round to Dressed Head On

Sample No.	Date of sample	General area where fish were taken	Number of fish	Average dressed weight-lbs.	Percent of loss (dressed weight-100%)
King Salmon					
1	July, 1948	Eureka	30	6.6	12.8
2	May-June, 1950	Scattered Redding Rock to Rockport*	38	6.4	15.4
3	July, 1950	Cresecent City	12	3.2	15.2
4	August, 1950	Fort Bragg	113	11.2	12.2
5	August, 1950	Princeton	28	14.6	12.4
6	August, 1950	Santa Cruz	6	19.8	15.2
			227	10.0	12.8
Silver Salmon					
7	May-June, 1950	Scattered Redding Rock to Rockport	13	4.3	14.2
8	July, 1950	Cresecent City	23	6.3	18.0
9	August, 1950	Fort Bragg	47	7.2	13.9
			83	6.5	15.0

* Redding Rock is about 33 miles north of Eureka. Rockport is about 17 miles north of Fort Bragg.

TABLE 2
Cleaning Loss of King Salmon by Size Groups

	Weight			
	Under 10 lbs.	10-14.9 lbs.	15-19.9 lbs.	20 lbs. and over
Number of fish	99	27	34	17
Cleaning loss	12.2	12.3	12.6	13.2

Loss is from round weight to weight dressed head on. Loss is expressed as percent of dressed weight.

AGE AND LENGTH COMPOSITION OF THE SARDINE CATCH OFF THE PACIFIC COAST OF THE UNITED STATES IN 1951-52¹

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This is the sixth report on the age and length composition of the catch of sardine (*Sardinops caerulea*) off the Pacific Coast of North America. Previous reports have presented data for the 1941-42 through 1950-51 seasons (Felin et al.).

During the 1951-52 season there was no fishery for sardines off the British Columbia, Washington, and Oregon coasts and no interseason fishery in California. The tables, therefore, give length and age composition for the regular California fishing season only. Trucking from one port to another was continued, but as in the past two seasons, all fish were referred to the port of landing rather than to the region where processed.

Sardines were landed in California at San Francisco, Moss Landing, Monterey, Morro Bay, and Port San Luis (all included in the Monterey totals); at Santa Barbara, Port Hueneme, Santa Monica, Los Angeles-Long Beach Harbor, and Newport (all included in the San Pedro totals); and at San Diego. The only delivery by boat to San Francisco was a load of 82 tons taken in the vicinity of Morro Bay. This tonnage was included in the Monterey landings for August.

For many years a fishery has been carried on off Baja California near Ensenada. At present there are three canneries processing sardines at this port. Throughout the 1951-52 season this fishery was sampled with fair regularity and the age and length composition of these samples are included with this report.

The system of scale sampling underwent slight modification this season. Five samples of 50 fish each were taken in the first half of the week and five in the last half. From these, scales were obtained from every fifth fish, which gave a random sample of all fish measured. To supplement our data on the outsized fish, extra scale samples were taken at all ports from all fish less than 181 mm. standard length, at San Pedro from all fish over 230 mm., and at Monterey from all fish greater than 240 mm.

Tables 1-6 show, by sex and region of catch, the length frequency distributions of fish of each year class from the random scale samples taken in the 1951-52 season.

Table 7 shows, by sex and region of catch, the mean length and standard error of the mean for each year class sampled in the 1951-52 season. These

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² Published by permission of the Director, U. S. Fish and Wildlife Service.

are based on the random scale samples taken and do not include the extra scale samples. They, therefore, represent the means of the frequency distributions of Tables 1-6.

Table 8 gives the calendar dates for the lunar months in the season.

Table 9 gives the numbers of fish, by region of catch and in each year class, caught during the season. The number of fish caught was estimated from the total weight landed at each port in each week divided by the average weight of the fish during that period. These were summed by lunar months and ports. The San Diego tonnages were prorated to numbers of fish from San Pedro average weights. The apportionment of numbers of fish among the several year classes caught each lunar month was accomplished by combining the random scale samples with the extra samples. From the age data, the percentage of each year class within each centimeter length stratum was calculated. These percentages were then weighted according to the length frequency distributions of the 50-fish samples. The resulting percentages were used in allocating the number of fish among the different year classes.

Scale samples and fish measurements were obtained at Monterey by Leo Pinkas and at San Pedro by Anita E. Daugherty. Sampling at Eureka was carried out by Orville P. Ball, Jr., and others from the United States Fish & Wildlife Service. Age determinations were made by the four authors. We wish to acknowledge with thanks the assistance of Mrs. Madalyn B. Murray in the laboratory and Mr. T. M. Widrig of the staff of U. S. Fish & Wildlife Service. Widrig (1951, p. 301) devised a method of computing the reliability of stratified samples. We arrived at the present method of sampling after comparing the reliability of age composition as estimated from random samples with that from stratified samples.

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TABLE 1
Length Composition of the 1950 Year-class, Age 1, in 1951-52

Length mm.	Monterey			San Pedro			California			Ensenada			Grand total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
174.....	1		1				1		1				1		1
176.....															
178.....															
180.....	1		1				1		1				1		1
182.....	1	2	3				1	2	3				1	2	3
184.....		1	1					1	1		1	1		2	2
186.....		3	3					3	3					3	3
188.....		1	1					1	1		1	1		2	2
190.....		1	1					1	1	2	2	4	2	3	5
192.....	1		1				1		1	1		1	2		2
194.....	1		1	1		1	2		2				2		2
196.....					1	1		1	1	1		1	1	1	2
198.....						1	1		1	1	1	2	2	1	3
200.....						1	1	1	1					1	1
202.....				1	3	4	1	3	4				1	3	4
204.....	1		1		2	2	1	2	3				1	2	3
206.....					1	1		1	1		1	1		2	2
208.....															
210.....															
212.....				1		1	1		1				1		1
214.....															
216.....					1	1		1	1					1	1
Totals.....	6	8	14	4	9	13	10	17	27	5	6	11	15	23	38

TABLE 2
Length Composition of the 1949 Year-class, Age 2, in 1951-52

Length mm.	Monterey			San Pedro			California			Ensenada			Grand total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
180.....	1		1				1		1	1		1	2		2
182.....	1		1				1		1				1		1
184.....										1		1	1		1
186.....										1		1	1		1
188.....	2	1	3		1	1	2	1	3	1		1	3	1	4
190.....		1	1					2	2	1	3	4	1	5	6
192.....				1		1	1		1	3		3	4		4
194.....					1	1	1		1	1	1	2	2	1	3
196.....				2	1	3	2	1	3		1	1	2	2	4
198.....	1		1	5	2	7	6	2	8	2	1	3	8	3	11
200.....		1	1	3	1	4	3	2	5				3	2	5
202.....				1	2	3	1	2	3	1		1	2	2	4
204.....	1	2	3	2	3	5	3	5	8				3	5	8
206.....				2	1	3	2	1	3		1	1	2	2	4
208.....		1	1	3	1	4	3	2	5	1		1	4	2	6
210.....				1		1	1		1				1		1
212.....					2	2		2	2					2	2
214.....				2		2	2		2				2		2
216.....	1		1	1		1	2		2				2		2
218.....				1	1	2	1	1	2				1	1	2
226.....					1	1		1	1					1	1
228.....				1		1	1		1				1		1
230.....		1	1	1		1	1	1	2				1	1	2
232.....		1	1				1	1	1					1	1
Totals.....	7	8	15	27	16	43	34	24	58	13	7	20	47	31	78

TABLE 3
Length Composition of the 1948 Year-class, Age 3, in 1951-52

Length (mm)	Monterey			San Pedro			California			Ensenada			Grand total		
	M	I	T	M	F	T	M	F	T	M	I	T	M	F	T
184										1		1	1		1
186										2	2	2		2	2
188										3	5	8	3	5	8
190	1		1	2	1	3	3	1	4	8	2	10	11	3	14
192				3	2	5	3	2	5	7	4	11	10	6	16
194				12	10	22	12	10	22	5	4	9	17	14	31
196				21	10	31	21	10	31	7	2	9	28	12	40
198	1		1	21	15	36	22	15	37	4	6	10	26	21	47
200	1	1	2	35	28	63	36	29	65	1	9	10	37	38	75
202	3	1	4	26	30	56	29	31	60		3	3	29	34	63
204	2	1	3	27	42	69	29	43	72		3	3	29	46	75
206	3	6	9	25	33	58	28	39	67	3	4	7	31	43	74
208	1		1	27	32	59	28	32	60	1	2	3	29	34	63
210	2	2	4	20	30	50	22	32	54		2	2	22	34	56
212	1	3	4	7	30	37	8	33	41				8	33	41
214	4	2	6	10	25	35	14	27	41	2		2	16	27	43
216	4	2	6	18	15	33	22	17	39				22	17	39
218		9	9	8	10	18	8	19	27				8	19	27
220	4	5	9	11	12	23	15	17	32	1		1	16	17	33
222	2	3	5	6	13	19	8	16	24				8	16	24
224	3	4	7	10	16	26	13	20	33				13	20	33
226	1	2	3	10	9	19	11	11	22		1	1	11	12	23
228	4	5	9	4	11	15	8	16	24				8	16	24
230	2	2	4	4	5	9	6	7	13				6	7	13
232	1	2	3		5	5	1	7	8				1	7	8
234	1		1		5	5	1	5	6				1	5	6
236		2	2		3	3		5	5					5	5
238	1	1	2	2	3	5	3	4	7				3	4	7
240		2	2	1	1	2	1	3	4				1	3	4
242				1	1	2	1	1	2				1	1	2
244	1		1				1		1				1		1
246		1	1					1	1					1	1
248		1	1					1	1					1	1
Totals	43	57	100	311	397	708	354	454	808	43	49	92	397	503	900

TABLE 4
Length Composition of the 1947 Year-class, Age 4, in 1951-52

Length mm.	Monterey			San Pedro			California			Ensenada			Grand total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
192.....				1		1	1		1	1		1	2		2
194.....				2		2	2		2				2		2
196.....				1	1	2	1	1	2	1		1	2	1	3
198.....				2		2	2		2		2	2	2	2	4
200.....				5	5	10	5	5	10				5	5	10
202.....				4	3	7	4	3	7	2		2	6	3	9
204.....	1		1	7	3	10	8	3	11				8	3	11
206.....		1	1	6	5	11	6	6	12	1		1	7	6	13
208.....	2		2	5	3	8	7	3	10				7	3	10
210.....	1		1	4	7	11	5	7	12				5	7	12
212.....				7	6	13	7	6	13				7	6	13
214.....		2	2	6	8	14	6	10	16	1		1	6	11	17
216.....	2	2	4	3	3	6	5	5	10				5	5	10
218.....	4	3	7	5	8	13	9	11	20				9	11	20
220.....	4	6	10	7	7	14	11	13	24				11	13	24
222.....	8	4	12	8	7	15	16	11	27				16	11	27
224.....	5	5	10	5	8	13	10	13	23				10	13	23
226.....	4	3	7	10	7	17	14	10	24				14	10	24
228.....	3	4	7	5	10	15	8	14	22				8	14	22
230.....	1	2	3	3	5	8	4	7	11				4	7	11
232.....	2	3	5	5	2	7	7	5	12				7	5	12
234.....	2	2	4	1	7	8	3	9	12				3	9	12
236.....	1	4	5	3	3	6	4	7	11				4	7	11
238.....				3	2	5	3	2	5				3	2	5
240.....	1		1	1	2	3	2	2	4				2	2	4
242.....		1	1		4	4		5	5					5	5
244.....		1	1	2	1	3	2	2	4				2	2	4
246.....															
248.....		1	1		1	1		2	2					2	2
250.....					1	1		1	1					1	1
Totals.....	41	44	85	111	119	230	152	163	315	5	3	8	157	166	323

TABLE 5
Length Composition of the 1946 Year-class, Age 5, in 1951-52

Length, mm.	Monterey			San Pedro			California			Ensenada			Grand total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
200										1	1			1	1
202					1	1		1	1					1	1
204				1		1		1					1		1
206				1	1	2		1	1	2			1	1	2
208				1	1	2		1	1	2			1	1	2
210				1		1		1		1			1		1
212	1		1		1	1		1	1	2			1	1	2
214	1	1	2	2	2	4		3	3	6			3	3	6
216	2	1	3	1	3	4		3	4	7			3	4	7
218	2	2	4	2	3	5		4	5	9			4	5	9
220	2		2	1	2	3		3	2	5			3	2	5
222	2		2	1		1		3		3			3		3
224	6	1	7	2	3	5		8	4	12			8	4	12
226	3	2	5	4	4	8		7	6	13			7	6	13
228	5	5	10	5	4	9		10	9	19			10	9	19
230	1	6	7	2	2	4		3	8	11			3	8	11
232		2	2	2	2	4		2	4	6			2	4	6
234	2	4	6	1	1	2		3	5	8			3	5	8
236	1		1		3	3		1	3	4			1	3	4
238	1		1					1		1			1		1
240					2	2		2	2					2	2
242		1	1	2		2		2	1	3			2	1	3
244	1		1		2	2		1	2	3			1	2	3
254					1	1		1	1					1	1
Totals	30	25	55	29	38	67	59	63	122	—	1	1	59	64	123

TABLE 6
Length Composition of the 1945 and 1944 Year-classes in 1951-52

Length mm.	1945 year-class, age 6									1944 year-class, age 7								
	Monterey			San Pedro			California			Monterey			San Pedro			California		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
202.....		1	1					1	1									
204.....																		
206.....																		
208.....					1	1		1	1									
210.....													1		1	1		1
212.....				2		2	2		2									
214.....					1	1		1	1				1		1	1		1
216.....				1		1	1		1				1		1	1		1
218.....					1	1		1	1	1	1					1		1
220.....	1		1		1	1		1	1	2								
222.....		1	1	1	2	3	1	3	4	1		1				1		1
224.....				1		1		1	1				1		1	1		1
226.....	1		1	1		1	2		2				1	2	2	1	2	2
228.....				1		1	1		1				1		1	1		1
230.....		1	1					1	1									
232.....					1	1		1	1									
234.....		1	1					1	1									
236.....	1	1	2				1	1	2									
238.....										1	1		1		1	1	1	2
240.....																		
242.....					1	1		1	1				1	1		1	1	
Totals.....	3	5	8	7	8	15	10	13	23	2	1	3	5	3	8	7	4	11

TABLE 7

Number of Fish, Mean Length, and Standard Error of the Mean for Each Year-class
in the 1951-52 Season by Region of Catch

Year-class	California						Baja California		
	Monterey			San Pedro			Lensenada		
	No.	M.	S.E.	No.	M.	S.E.	No.	M.	S.E.
1950									
Male	6	188	5.02	4	202	3.88	5	193	2.22
Female	8	186	2.18	9	204	1.86	6	193	3.52
Totals	14	186	5.10	13	203	1.68	11	193	1.94
1949									
Male	7	194	5.00	27	205	1.88	13	193	2.20
Female	8	207	5.86	16	205	2.22	7	195	2.36
Totals	15	201	4.10	43	205	1.42	20	193	1.58
1948									
Male	43	217	1.84	311	208	.56	43	196	1.16
Female	57	221	1.50	397	211	.52	49	198	1.10
Totals	100	219	1.16	708	209	.40	92	197	.80
1947									
Male	41	223	1.30	111	217	1.16	5	200	2.48
Female	44	226	1.42	119	221	1.12	3	203	5.50
Totals	85	224	.94	230	219	.80	8	201	2.40
1946									
Male	30	225	1.58	29	224	1.96			
Female	25	228	1.70	38	226	1.94	1	200	
Totals	55	227	1.06	67	225	1.34	1	200	
1945									
Male	3	227	12.08	7	220	3.98			
Female	5	225	8.30	8	222	4.78			
Totals	8	226	5.30	15	221	2.68			
1944									
Male	2	220		5	223	7.10			
Female	1	238		3	231	13.86			
Totals	3	226	12.08	8	226	5.10			

TABLE 8

Calendar Dates of Lunar Months for the 1951-52 Season

"July"	July 19-August 17
"August"	August 18-September 15
"September"	September 16-October 15
"October"	October 16-November 13
"November"	November 14-December 13
"December"	December 14-January 11
"January"	January 12-February 10

TABLE 9
Age (Year-class) Compositions of the Sardine Catch in the 1951-52 Season
(Numbers of fish are given in thousands, i.e., 000 omitted)

Catch		Number of fish by age (year-class)							
Tons	Number	1	2	3	4	5	6	7	8
		1950	1949	1948	1947	1946	1945	1944	1943
Monterey									
"July"	839	478	130	1,845	1,102	1,341	302		
"August"	7,622	4,460	1,212	17,208	10,276	12,506	2,811		
"September"	2,975	65	2,015	14,238	2,037	3,251	65		
"October"	3,446	21,719	434	8,427	7,602	3,193	174	369	
"November"	824	637	266	1,593	1,912	690	143	69	
"December"	28	26	11	64	77	28	6	3	
Totals, Monterey	15,734	6,100	5,154	43,375	23,006	21,009	3,501	441	
San Pedro									
"September"	54,624		27,132	324,272	66,080	14,879	5,251		
"October"	37,257	1,643	12,046	185,626	53,388	16,427	3,285	1,095	274
"November"	10,722	956	2,918	52,192	16,972	4,622	1,673	319	
"December"	6,409	1,394	26,860	12,407	12,407	3,392	604	558	
"January"	1,056	144	194	4,329	1,736	598	115	87	
Totals, San Pedro	110,068	4,137	43,575	593,279	150,583	39,918	10,928	2,059	274
San Diego	1,343	141	393	6,558	2,146	625	151	60	
Grand totals	127,145	10,378	49,122	643,212	175,735	61,552	14,580	2,560	274

NOTES

YELLOW SABLEFISH (BLACK COD) TAKEN IN MONTEREY BAY

A predominantly yellow sablefish (black cod), *Anoplopoma fimbria*, was caught in Monterey Bay on September 14, 1951, by S. Gianino and the crew of the fishing vessel RITA MARIE while fishing baited longlines for sablefish in about 175 fathoms, 10 miles southwest of Pt. Santa Cruz. The specimen, 22½ inches total length, was left in the care of the General Fish Corporation, Santa Cruz. Its bright yellow color was in striking contrast to the rather drab slaty color of a normal specimen. There were some vestigial smudges of dusky-black in a few places on the body (Figure 1) and the color of the iris of the eye was a normal black. Two fishermen, Gus and Luigi Canepa of Capitola, who have fished sablefish since 1925, said that they had never seen a yellow individual before.



FIGURE 1. (TOP) Normal, slaty-black, adult sablefish. This fish bears a yellow tag under the first dorsal fin and was recovered 3½ months after tagging. (MIDDLE) "Calico" phase of sablefish. This fish bears a red tag under the first dorsal fin and was recovered three months after tagging. (BOTTOM) Abnormal, predominantly yellow sablefish, taken in Monterey Bay, September 14, 1951. Photograph by J. B. Phillips.

Although adult sablefish are quite slaty-black, smaller fish are lighter in color and usually whitish along the belly. Occasionally, but not uncommonly, intermediate-sized specimens are encountered that have a mottled

appearance of light-gray and slaty-black. Sometimes there is a light yellow tinge to these lighter areas. This "calico" phase may be a half-way step between the normal dusky-black and the bright yellow color of this unusual specimen.—*J. B. Phillips, Bureau of Marine Fisheries, California Department of Fish and Game, January, 1952.*

AN OCCURRENCE OF THE NATURAL DESTRUCTION OF HAKE IN HUMBOLDT COUNTY

A large number of Pacific hake (*Merluccius productus*) became accidentally stranded and perished on Humboldt County beaches on June 27, 1951. Dead hake were found on every sandy beach observed from the mouth of Redwood Creek to the mouth of the Mad River, a distance of about 30 miles. A few to several hundred fish were found on each beach indicating that the total kill probably numbered in the thousands.



FIGURE 1. Showing smelt and silversides in mouths of hake taken from Moonstone Beach.
Photograph by John W. Westgate.

The hake had been feeding on smelt (*Osmeridae*) and silversides (*Atherinidae*) in the shallow surf on an outgoing tide. As the tide receded the fish became stranded. The first trapped fish were noticed at about 11 p.m. on Moonstone Beach. A short time afterwards 46 specimens were collected along a few hundred feet of shore line. On the following day most of the accessible beaches from Redwood Creek to Mad River were examined and additional dead hake observed.

When they became trapped almost every hake had been in the process of swallowing whole, smelt or silversides, which were found head or tail first in the mouths, gullets, and stomachs.

The average fork length of the 46 specimens collected was 59.7 cm. and the average weight was 2.75 pounds.—*John W. De Witt, Jr., Humboldt State College, Arcata, California, February, 1952.*

THE CASE OF THE ARTESIAN STICKLEBACKS

On or about the fifth of February, 1952, workmen completed the digging of a 600-foot well on the ranch of Howard Jack in the Cholame Valley near Shandon, California. Soon after the artesian water began flowing over the ground some small fish were seen in it. The workmen believed that the animals came up from an underground river or cavern. Their story created a wide flurry of interest and was reported through the nation-wide news services and over the radio. The story developed exciting turns such as, "one-inch-long tuna . . . imprisoned by an earthquake thousands of years ago . . . spumed onto (the) property by the hundreds . . . cascaded up in fountains and fell flopping to the ground."

On the ninth of February Mr. David Thomson, Mr. William Thurmond and I, all of the Biological Sciences Department, California State Polytechnic College, San Luis Obispo, went to Howard Jack's ranch to investigate. We talked to the foreman in charge of the digging who had first reported finding the fish. He explained the absence of more fish coming from the well by the fact that gravel had been poured between the 14-inch perforated casing and the wall of the 27-inch bore. Water was gushing from the well at the rate of about 1,500 gallons per minute. It created a small stream which joined the Cholame River about a mile away. Within 20 feet of the well we found one three-spined stickleback (*Gasterosteus aculeatus*). The foreman identified it as the same as those which "came out of the well." Twenty-five yards away we found two more. There were many in the Cholame River.

Judging from the geological history of the valley and from the soil brought up by the digging operations, it seems unlikely that there could be spaces large enough for even these small fish to have been carried underground from some river or lake. A more plausible explanation is that when the whole area was more or less flooded two weeks before the well was dug, the fish came from the Cholame River and spread over the entire valley wherever there was water. When the rains stopped and the water receded it left isolated pools in which the fish were trapped. These pools could be so small and hidden from view in low depressions that to a casual observer the whole area would seem dry. The foreman told us that two weeks before the well was dug there was six inches of water in the old river bed within 100 yards. We believe that as soon as the new well water encountered one of these pools the trapped fish swam upstream and soon were noticed by the workmen. Their conclusion that the fish came from the well is readily understood.—Glenn A. Noble, *California State Polytechnic College, San Luis Obispo, February, 1952.*

Correction: The correct name and address of the sales agent for "The Oyster Industry of Willapa Bay, Washington" by Trevor Kincaid, reviewed in the April, 1952, issue is:

Calliostoma Co.
1904 East 52d Street
Seattle, Washington

REVIEWS

The Lure and Lore of Trout Fishing

By Alvin R. Grove, Jr.; The Stackpole Company, Harrisburg, Pa., 1951; v + 318 p.; \$5. Illustrated by Pearce-Bates.

Dr. "Bus" Grove, Professor of Botany at Pennsylvania State College, has produced a scholarly appearing and well organized book. If the jacket summary is too blatant with praise, and if the title fails to indicate the book's restricted subject matter, the fault cannot be charged to the author. Dr. Grove writes with modesty and restraint about flies and fly fishing on trout streams in Pennsylvania and New York State. He does not try to impress the reader with a vast and final knowledge of his subject, although the information he presents proves him sufficiently capable. Neither does he go overboard with tales of multitudinous trout he has caught, nor brag of taking the biggest fish in the stream. His own angling experiences are related but briefly and only for the purpose of making a point.

Three of the book's nine chapters deserve special mention. One on "Naturals and Artificialis" attempts to relate the scientific names of insects to the names of well known artificials. I looked forward with interest to this, but must confess that the quantity of material discouraged me. I agree with the author that the names should be standardized and reduced in number. Of particular merit is the chapter "To Tie a Fly." Dr. Grove says that "to write lucid instructions for tying a fly is next to impossible . . . the real answer lies, apparently, in the opportunity to sit down with someone trying to learn to tie a fly and to show him how to do it, rather than to explain in words." Nevertheless, he tries to overcome the difficulties with 32 pages of basic, detailed instructions. I commend the quality of these lessons from personal experience. The chapter "Cause and Effect" is a good, short lesson in fishery biology for the angler who is curious but unwilling to take the full course. It includes a section on "Our Future Fishing" which is one of the clearest and most enlightened statements about modern fish conservation problems that I have read in a recent, popular-type fishing book.

A list of references contains 68 titles ranging by author from Dame Juliana Berners and Izaak Walton to Art Flick and Vincent Marinaro. Among them are 17 strictly academic papers regarding aquatic invertebrates by specialists like Claassen, Comstock, Johannsen, Lloyd, and J. G. Needham.

"The Lure and Lore of Trout Fishing" is not the magnificent, modern classic the publisher claims it to be, but it is a sound book and I recommend it as a worthy addition to the angler's library.—*Herbert E. Pintler, California Department of Fish and Game.*

Survey of Marine Fisheries of North Carolina

By Hardin F. Taylor and a staff of associates; University of North Carolina Press, Chapel Hill, 1951; xii + 555 p. \$10.

Envisioned as a summary of existing knowledge—"the point of departure from which future researches might begin"—this book is all that and more. Despite its limiting title, nearly 120 of the pages are devoted to a general study of fisheries economics and the balance of the text is liberally interspersed with comments of far more than local interest. Well presented and well documented, it forms a reference with which all those concerned with the problems of fisheries should be familiar.

The first of the three major sections comprising the volume is "Hydrography of North Carolina Waters" by Nelson Marshall. The available data are scanty, and he points out the need for intensive hydrographic and ecological studies. Based upon his estimate of the region's total production of basic food, he suggests that the state's waters might support a far greater fishery yield than is presently being realized.

Part II is entitled "Biology and Natural History of the Economic Species." It includes articles on the menhaden (W. A. Ellison), fin-fishes (E. W. Roelofs), oyster and other molluscs (A. F. Chestnut), shrimps (C. Broad), blue crab (J. C. Pearson), terrapin (R. E. Coker), seaweed resources (H. J. Humm), and marine angling (F. LaMonte). In his introduction to this section, Dr. Taylor discusses briefly the

causes of change in abundance of marine fishes. These he ascribes largely to natural factors—though he remarks that fishing may have some effect. He feels that legislation usually comes when a fishery is at a low point in a natural cycle so that when the cycle swings upward it is the restrictions which are credited for the gain. It is his contention that much more study is required to determine whether restrictive measures are actually justifiable either economically or biologically, that, until fishery dynamics are better understood, "fishery management" by public regulation is little more than vain presumption."

Part III, "Economics of the Fisheries of North Carolina" by Dr. Taylor, includes a lengthy discussion of general fishery economics. It is his belief that, while public thinking and policy making are usually based on the assumption that purely biological factors of abundance are the chief determinants of fishing community welfare, economic factors should receive equal consideration, for consideration of biological factors only is certainly one-sided and may be erroneous. Scarcity may not be a calamity to the fisherman, for even uncontrolled scarcity may leave him as well off in terms of income. Despite fluctuations of individual species, the fisheries of North America and of its major regions have never been exploited to point of diminishing returns, and in the long run, economic forces result in adjustments without regulation.

He considers at length the role of American fisheries in relation to the general economy, particularly to agriculture, and the specific problems and handicaps of the fisheries. Earning power, capital requirements, marketing setups, distribution, utilization, quality and standards, fishermen's organizations, dietary patterns and the effects of legislation exemplify the diversity of this section's topics. Dr. Taylor believes that fishing in general is an unprogressive industry which fails to attract venture capital because of a reputation of not being a particularly profitable business; that the effect of most legislation has been to enforce inefficiency, which keeps costs high and consequently benefits agriculture; that technological improvements lag far behind agriculture; that there is vast room for improvements in fishing efficiency but should improvements be found they might well "be forbidden by law or labor unions"; that production is not what it might be, the high cost of distribution offsetting the initial low cost of fish products; that among the major problems facing the industry are the development of greater efficiency of operations, greater utilization, improvement of the means of distribution and the development of markets, together with a re-examination of the roles of conservation and of legislation.

While many will take strong exception to certain of the beliefs and philosophies expounded, all will agree that Dr. Hardin and his associates have surpassed their initial objectives and rendered a fine service to the fishing world as well as to the state of North Carolina.—*Phil M. Roedel, California Department of Fish and Game.*

Waves and Tides

By R. C. H. Russell and D. H. Macmillan; Hutchinson's Scientific and Technical Publications, London, New York, 1952; 348 p., 17 plates, 100 + figs. \$3.75.

To the interested observer at the seashore who wonders about waves and tides and the reasons therefor, this book will give many of the answers. He will learn much if he has no knowledge of physics or mathematics but with some mathematical background his reading will be more profitable. To the administrator who is faced with decisions about construction of breakwaters and clearing channel entrances, this book will be of material aid in understanding the reports of the engineers. The navigator also will find basic information to aid him in interpreting and understanding tide and hydrographic tables. The marine biologist in his turn should list this book among his oceanographic references which give essential background to an understanding of the environment of the plants or animals he is studying.—*Frances N. Clark, California Department of Fish and Game.*

Mexican Birds: First Impressions

By George Miksch Sutton; University of Oklahoma Press, Norman, 1951; 282 p., illustrated by the author. \$10.

It is the subtitle that best conveys the character of Dr. Sutton's narrative for this is the record, written from his field notes, of his initial impressions of Mexican birds gained on his first expedition to the republic. His travels on this occasion were made during the winter months and were confined to the northeastern states of Tamaulipas, Nuevo León and Coahuila. Thus his account is confined to the birds found at that time of the year in that area. Consequently, it is not—nor does it pretend to be—a complete

guide to Mexican birds. It is, however, full of interesting and valuable information. It makes good reading, though at times, when the author is trying to project his emotions to his reader, the prose becomes a bit labored.

The narrative is followed by an appendix occupying some 70 pages which briefly describes and gives the distribution of those species found in Mexico which do not range into the United States. The species common to both countries are mentioned but not described. This appendix draws on published and unpublished source material, including the author's own data gathered on other trips. It will prove particularly valuable to visitors in any part of the country.

The book's outstanding feature is the fine illustrations drawn by the author—65 pen-and-ink drawings and 16 water colors. Dr. Sutton has that gift of giving life as well as exact portraiture to his subjects and he is to be envied.

Finally, the University of Oklahoma Press is to be congratulated for its production of a handsome volume.—*Phil M. Roedel, California Department of Fish and Game.*

Under the Sea-wind

By Rachel L. Carson; Oxford University Press, New York, 1952, 314 p. \$3.50.

Close on the heels of Miss Carson's best-seller comes this reissue of her first book. Published originally in 1941, it apparently had little circulation, very likely because of our entry into the war as the dust cover suggests. This is a tale of life and death in the sea and along the shore woven around a bird, the black skimmer, and two fishes, the Atlantic mackerel and eel. It will certainly be an eyeopener to those whose contact with biology is limited, giving as it does a vivid account of the odds against individual survival and the unremitting battle for food and life which is the lot of most living things. It is a good book, worthy of a second edition and a large sale. The technical reader will find little to quibble over and the general reader will find it nearly—if not quite—as fascinating as "The Sea Around Us."—*Phil M. Roedel, California Department of Fish and Game.*

Adventures With Reptiles. The Story of Ross Allen

By C. J. Hylander; Julian Messner, Inc., New York, 1951; xii + 174 p., 12 photographs. \$2.75.

This book is written by a man who has taught biology in high school and college, directed nature study work in summer camps, and written a number of textbooks and popular books on nature. The present volume is a popular one which, while it might interest amateur reptile lovers of all ages, is aimed largely at young people of about high school age.

The book deals in part with the life and adventures of Ross Allen, who maintains a reptile exhibit at Silver Springs, Florida, and runs a large animal supply business out of nearby Ocala, specializing in live reptiles and amphibians. Ross is an expert collector, and has spent a great part of his life in the field, observing and collecting animals of all sorts. The reviewer once had the pleasure of spending two days collecting with him during a memorable spring trip to Florida.

The greater part of the book deals with the animals themselves, drawing from Ross's great fund of information on their behavior, feeding habits, breeding, and the like, and therefore dealing mainly with Florida forms. There are sections on the extraction of snake venom and its use in making antivenin; on alligators and crocodiles; on poisonous snakes and treatment of their bites; on certain nonpoisonous snakes; on collecting expeditions in the Everglades and elsewhere; and on care of reptiles in captivity.

The presentation of the material lacks the color which characterizes the work of some nature writers, but it makes fairly interesting reading. There is an abundance of quite accurate information within the field covered, and the book seems relatively free of errors.

Even in a popular book of this sort I would like to see scientific names given in addition to the popular ones. The advanced herpetologist may occasionally wonder about the identification of some of the less familiar forms, while the eager young beginner deserves this aid in learning scientific names, essential if he is to carry this study much further.—*Anita E. Daugherty, California Department of Fish and Game.*

RECENTLY RECEIVED

Migration of Birds

By Frederick C. Lincoln; illustrated by Bob Hines; Doubleday and Co., New York, 1952, 102 p. \$1.00.

This authoritative book originally appeared as Circular 16 of the U. S. Fish and Wildlife Service which was issued in pamphlet form in 1950. This edition is identical with the circular except for the hard cover, an advantage, and a smaller page size, perhaps a disadvantage in that the type suffers somewhat in clarity with the reduction. In a book as small as this, the treatment is of necessity general, but it does give an excellent perspective of current knowledge. The general reader will find his dollar well spent.

Notes on the Bobcats (Lynx rufus) of Eastern North America With the Description of a New Race

By Randolph L. Peterson and Stuart C. Downing, Royal Ontario Museum of Zoology and Palaeontology, Toronto, Contribution 33, 33 p., 7 figs., 1952, paper.

Describes a new subspecies (*L. r. superiorensis*) from the western Great Lakes region and reviews the distribution and status of bobcats in Ontario.

The Food of the Albacore (Germa alalunga) Off California and Baja California

By J. L. McHugh, Scripps Institution of Oceanography, La Jolla, Calif., Bulletin, vol. 6, no. 4, p. 161-172, 4 figs., paper.

An examination of 321 stomachs from fish collected in the summers of 1949 and 1950 showed 65 percent of the food by volume to be fishes and 35 percent invertebrates. The saury (*Cololabis saira*) was by far the most important item, comprising about 50 percent of the volume.

REPORTS

FISH CASES

January, February, March, 1952

Offense	Number of arrests	Fines imposed	Jail sentences (days)
Abalone: Closed season; no license; overlimit; undersized; out of shell; failure to show license	104	\$3,127 00	
Angling: No license; alien using citizen license; 2 poles; night fishing; possessing gaff within 300 ft. river; fishing closed stream; using 7 hooks; angling closed district; failure to show license on demand; operating set line; possessing gill net in Dist. 1 ¹ / ₂ ; false statement on license application; treble hooks; fishing from fish ladder; angling too near dam; unattended pole; taking fish other than by angling; no nonresident license	167	2,430 00	5
Bass, striped: Angling with 2 poles	11	200 00	
Catfish: Undersized; closed season; no license; overlimit; night fishing; netting	13	790 00	
Clam: Pismo: undersize, overlimit, no license, failure to return to hole, out of shell; overlimit and undersize cockles; taking after hours; no license; overlimit big necks; overlimit Washingtons; possessing digging instruments on clam preserve	224	6,880 50	30
Commercial: Taking abalone Dist. 19A; predating license in bait shop; possessing crabs, closed season, no storage receipts; failure to submit tax statements; failure to post bag limits on party boat; trawl net, Dist. 19; no commercial license; offering undersize tuna for sale; possessing undersize lobsters in commercial market; using round haul net Dist. 19A; restaurant possessing undersize lobsters; undersize halibut; striped bass in commercial market; fisherman possessing female crabs; no tax and weight returns filed; failure to fill out and return fish receipts; failure to keep trawler log records; processor possessing undersize abalone; selling undersize crabs; set net Dist. 12; gill net Dist. 3; canning sardines taken for bait; possessing beam trawl; no boat registration	53	6,670 00	
Crab: Undersize; taking females	3	85 00	
Carp: Taking by means other than angling	2	50 00	
Pollution: Oil; explosives; bluestone; sawdust	20	2,050 00	
Rockfish: Taking without license	2	20 00	
Salmon: Spearing; snagging; shooting	4	100 00	
Sturgeon: Taking fully protected fish, no license	1	35 00	
Sunfish: Netting; taking closed season; no license	5	105 00	
Trout: Closed season; no license; spearing; taking from private pond; overlimit; treble hooks; 2 rods	28	831 00	
Total	637	\$23,373 50	35
Confiscated abalone sold		52 25	
Confiscated lobsters sold		2,131 50	
Grand total		\$25,557 25	

GAME CASES

January, February, March, 1952

Offense	Number of arrests	Fines imposed	Jail sentences (days)
Bear: Trapping, closed season	1	\$25 00	
Coots: Closed season	1	50 00	
Deer: Allowing dogs to run in closed season; illegal transport into California; no license, spike buck; closed season; taking doe; illegal transport and failure to declare; altering and defacing deer tag; permitting dogs to kill deer; spotlighting; no tags; possessing illegally taken deer; using another's permit; taking at night; 22 rifle; using another's deer tags; failing to have tag validated; possessing untagged deer; illegal license	80	6,702 50	565
Deer meat: Possession, closed season; untagged; illegal possession; possessing and buying	33	2,853 00	386
Dove: Closed season	1	25 00	
Duck: Late shooting; closed season; shooting from power boat; unplugged gun; no license; overlimit; bringing overlimit from Mexico; possessing gun in refuge; failure to declare; taking with 22 rifle; possessing in refuge; failure to show license; early shooting; illegal transportation into California	115	5,599 50	
Elk: Illegal transportation; no tags; illegal license; failure to declare	3	275 00	
Goose: Closed season; overlimit; late shooting	21	697 50	
Hunting: Loaded gun in car; no license, gun in refuge; hunting on closed cooperative; spotlighting; false statement on license; night hunting; unplugged gun; trespassing; hunting on cooperative without permit; failure to show license; late shooting; unplugged gun in refuge; possessing crossbow in game refuge; trapping without license; transferring license; no back tag; shooting from public road; predating license	221	4,932 50	10
Nongame birds: Taking golden eagle, snipe, shorebirds, glossy ibis, robins	7	60 00	
Partridge: Closed season	1	30 00	
Pheasant: Shooting from car; closed season; loaded gun in car; failure to tag; failure to punch tags; taking hen; late shooting; unplugged gun; shooting from automobile; trespassing on cooperative area; using another's tags; taking with 22	47	2,680 00	
Pigeon: Closed season	3	60 00	
Quail: Closed season; possessing illegal quail; taking with unplugged gun	8	360 00	
Rabbit: Closed season; no license; at night; hunting from car; spotlighting; late shooting; loaded gun in car; using another's license	54	1,795 00	77½
Squirrel: Taking tree squirrel; closed district	3	100 00	
Swan: Shooting; possessing freshly killed swan	5	325 00	
Total	604	\$26,570 00	1,038½

SEIZURES OF FISH AND GAME

January, February, March, 1952

	Number	Pounds
Fish:		
Abalone.....	438	51½
Bass.....	11	.....
Carp.....	31	.....
Catfish.....	68	1,400
Clam.....	1,089	3
Crab.....	136	40
Crappie.....	189	.....
Halibut.....	.....	621
Lobster.....	98	253
Salmon.....	1	.....
Sturgeon.....	1	.....
Sunfish.....	33	.....
Trout.....	50	.....
Game:		
Coot.....	3	.....
Deer.....	37	.....
Deer Meat.....	.....	682
Dove.....	4	.....
Duck.....	436	.....
Elk.....	.....	50
Goose.....	32	.....
Mudhen.....	11	.....
Nongame Birds.....	7
Partridge.....	1
Pheasant.....	50
Pigeon.....	6
Quail.....	14
Rabbit.....	32
Squirrel.....	3
Swan.....	5

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